112th Congress, 2d Session – – – – – – – – – – – – – House Document 112–130

FEASIBILITY REPORT AND ENVIRONMENTAL IMPACT STATEMENT: FARGO-MOORHEAD METROPOLITAN AREA FLOOD RISK MANAGEMENT, JULY 2011

COMMUNICATION

FROM

THE ASSISTANT SECRETARY OF THE ARMY, CIVIL WORKS, THE DEPARTMENT OF DEFENSE

TRANSMITTING

THE CORPS FINAL FEASIBILITY REPORT AND ENVIRONMENTAL IMPACT STATEMENT

PART 1 OF 7

AUGUST 2, 2012.—Referred to the Committee on Transportation and Infrastructure and ordered to be printed

U.S. GOVERNMENT PRINTING OFFICE

82–386 WASHINGTON : 2013

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY
CIVIL WORKS
108 ARMY PENTAGON
WASHINGTON DC 20310-0108

APR - 3 2012

Honorable John A. Boehner
Speaker of the House
of Representatives
Washington, D.C. 20515

Dear Mr. Speaker:

In response to a Senate Resolution adopted September 30, 1974, by the Committee on Environment and Public Works, the Secretary of the Army recommends authorization of the Fargo-Moorhead Metropolitan Area, North Dakota and Minnesota flood risk management project. The proposal is described in the Report of the Chief of Engineers dated December 19, 2011, which includes other pertinent reports and comments. The views of the State of North Dakota, State of Minnesota, and the Department of the Interior are set forth in the enclosed communications. The Secretary of the Army plans to implement the project at the appropriate time, considering National priorities and the availability of funds.

The recommended plan would provide flood risk management and recreation to the greater Fargo, North Dakota and Moorhead, Minnesota metropolitan area. The recommended flood risk management plan consists of a 36-mile-long diversion channel with a 20,000 cubic-feet-per-second (cfs) discharge capacity. The channel would start approximately four miles south of the confluence of the Red and Wild Rice rivers, extend west and north around the North Dakota cities of Horace, Fargo, West Fargo and Harwood, and ultimately re-enter the Red River of the North downstream of the confluence of the Red and Sheyenne rivers near Georgetown, Minnesota. The channel would cross the Wild Rice, Sheyenne, Maple, Lower Rush, and Rush rivers and incorporate the existing Horace to West Fargo Sheyenne River diversion channel. The main line of protection at the south end of the project would include the embankments adjacent to the diversion channel, floodwater storage area embankments, and two tie-back levees. Unavoidable environmental impacts would be mitigated by constructing fish passage channels along the Red and Wild Rice River structures, constructing additional fish passage projects in the Red River basin, restoring streams on tributaries near the project, converting floodplain agricultural land to floodplain forest, and creating wetlands within the diversion channel footprint. These mitigation features would be monitored and adaptively managed for up to 20 years to ensure their performance. The recommended recreation plan includes 44 miles of recreational trails, trailheads with support facilities, benches and interpretive signage. The recommended plan deviates from the National Economic Development (NED) Plan and is the locally preferred plan.

Based on October 2011 price levels, the estimated first cost of the recommended flood risk management plan is approximately $1,745,033,000. The plan would protect the communities against the 1-percent-chance flood event. It would reduce average annual flood damages by 84 percent and leave average annual residual damages estimated at $32,000,000. Based on a 4.0-percent discount rate and a 50-year period of analysis, the total equivalent average annual costs for flood risk management, including operations, maintenance, repair, replacement, and rehabilitation (OMRR&R), are estimated to be $98,098,000. The average annual flood risk management benefits are estimated at $174,617,000 with net average annual benefits of $76,519,000 and a benefit-to-cost ratio of 1.8 to 1.

Since the recommended plan provides fewer benefits for flood risk management than the NED Plan, the Federal cost share is limited to the Federal share of the least cost plan that would provide similar benefits. The estimated first cost of the least cost plan is $1,205,207,000, and in accordance with Section 103 of the Water Resources Development Act of 1986, as amended, the estimated Federal share for that plan and the recommended plan is approximately $783,384,000 (44.9 percent of the recommended plan). The non-Federal sponsors would be responsible for the remainder of the costs of the recommended flood risk management features, resulting in a non-Federal cost share estimated at about $961,649,000 (55.1 percent).

The estimated first cost of the recommended recreation features is $36,315,000 and the total equivalent average annual cost, including OMRR&R, is estimated at $1,854,000. The average annual recreation benefits are estimated at $5,130,000 and the estimated net average annual benefits are $3,276,000. The benefit- to-cost ratio for recreation is 2.8 to 1. In accordance with Section 103 the Federal and non-Federal shares for separable recreation costs are estimated at $18,157,500 (50 percent) each.

The total estimated first cost of the recommended plan is $1,781,348,000. The total equivalent average annual cost, including OMRR&R, is estimated at $99,952,000. The equivalent average annual benefits are estimated to be $179,747,000 resulting in total net average annual benefits of $79,795,000 and an overall project benefit-to-cost ratio of 1.8 to 1. The total Federal share of first costs is estimated at $801,542,000 (45.0 percent), and the total non-Federal share is estimated at $979,806,000 (55.0 percent).

The Office of Management and Budget advises that there is no objection to the submission of the report to the Congress. However, OMB also advises that should Congress decide to authorize this project for construction, to please be aware that the project will be required to compete for funds with other proposed investments considered in future budgets. A copy of OMB's letter dated March 28, 2012, is enclosed. I am providing a copy of my letter to the House Committee on Appropriations Subcommittee on Energy and Water Development, and the House Committee on Transportation and Infrastructure Subcommittee on Water Resources and Environment. I am providing an identical letter to the President of the Senate.

Very truly yours,

Jo-Ellen Darcy

Jo-Ellen Darcy
Assistant Secretary of the Army
(Civil Works)

Enclosures

8 Enclosures
1. Report of the Chief of Engineers, December 19, 2011
2. Record of Decision, dated, April 3, 2012
3. OMB Clearance Letter, dated, March 28,2012
4. Department of the Interior Letter to USACE, October 24, 2011
5. USACE Response to Department of the Interior, December 22, 2011
6. State of North Dakota Letter to USACE, November 07, 2011
7. State of Minnesota Letter to USACE, November 04,2011
8. Feasibility Report and Environmental Impact Statement, July 2011, as revised November 2011

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20314-1000

REPLY TO
ATTENTION OF

CECW-MVD (1105-2-10a)

DEC 19 2011

SUBJECT: Fargo-Moorhead Metropolitan Area Flood Risk Management Project, North Dakota and Minnesota

THE SECRETARY OF THE ARMY

1. I submit for transmission to Congress my report on flood risk management in the Fargo-Moorhead metropolitan area of North Dakota and Minnesota. It is accompanied by the report of the district and division engineers. These reports are in response to a resolution of the Senate Committee on Public Works, adopted 30 September 1974. The resolution requested the review of "reports on the Red River of the North Drainage Basin, Minnesota, South Dakota and North Dakota, submitted in House Document Numbered 185, 81st Congress, 1st Session, and prior reports, with a view to determining if the recommendations contained therein should be modified at this time, with particular reference to flood control, water supply, wastewater management and allied purposes." Preconstruction engineering and design activities will be continued under the authority provided by the resolution cited above.

2. The reporting officers recommend authorization of a plan to reduce flood risk in the Fargo-Moorhead metropolitan area by constructing a diversion channel within North Dakota combined with upstream floodwater staging and storage. The recommended plan consists of a 36 mile 20,000 cubic feet per second (cfs) diversion channel that would start approximately four miles south of the confluence of the Red and Wild Rice rivers and extend west and north around the North Dakota cities of Horace, Fargo, West Fargo and Harwood and ultimately re-enter the Red River of the North downstream of the confluence of the Red and Sheyenne rivers near Georgetown, Minnesota. The diversion channel would cross the Wild Rice, Sheyenne, Maple, Lower Rush and Rush rivers and incorporate the existing Horace to West Fargo Sheyenne River diversion channel. The main line of protection at the south end of the project includes the embankments adjacent to the diversion channel, floodwater Storage Area 1 embankments, and two tie-back levees. Project features would be located in both North Dakota and Minnesota. Unavoidable environmental impacts would be mitigated for with construction of fish passage structures along the Red and Wild Rice rivers; construction of additional fish passage projects in the Red River basin; stream restorations on tributaries near the project; conversion of floodplain agricultural land to floodplain forest; and creating wetlands within the diversion channel footprint. These mitigation features along with adaptive management would be monitored for up

Enclosure 1

to twenty years to ensure their performance. This would include pre- and post-project monitoring. The recommended plan is a deviation from the national economic development (NED) plan and is the locally preferred plan (LPP).

3. The currently identified NED Plan is a diversion channel located east of Moorhead, MN with a capacity of 40,000 cfs. The NED Plan diversion channel would be approximately 25 miles long with approximately 10 miles of tie-back levees and includes a large control structure on the Red River of the North. The NED Plan would reduce the stage from the 0.2 percent flood event from approximately 46.7 to 37.6 feet on the Fargo gage.

4. The recommended LPP (following an alignment in North Dakota) would reduce flood stages on the Red River to a lesser degree than the NED plan (following an alignment in Minnesota); the LPP would reduce the stage from the 0.2 percent flood event from approximately 46.7 to 40.0 on the Fargo gage. But the LPP would benefit a larger geographic area and address flooding on four tributaries to the Red River that are not addressed by the NED plan. The LPP provides approximately $6,000,000 less in average annual flood risk management benefits than the NED plan. Since the LPP provides fewer average annual benefits than the NED plan, a comparable smaller scale plan with similar outputs to the LPP was identified along the NED alignment to set the Federal cost share. This plan was identified as the Federally Comparable Plan (FCP) and serves as the basis to determine the project cost sharing apportionment. Federal investment in the flood risk management features of the LPP is capped at the investment that would have been made for the FCP. Based on October 2011 price levels, the estimated first cost of the FCP flood risk management features is $1,205,207,000. In accordance with the cost sharing provisions of Section 103 of the Water Resources Development Act (WRDA) of 1986, as amended, the Federal share of the first cost of the FCP flood risk management features is estimated at $783,384,000 (65 percent).

5. Based on October 2011 price levels, the estimated first cost of the recommended LPP is $1,781,348,000. The first cost of the recommended LPP includes approximately $1,745,033,000 for flood risk reduction and approximately $36,315,000 for recreation. In accordance with Section 103 of WRDA 1986, as amended, recreation features would be shared 50 percent Federal and 50 percent non-Federal. Federal cost sharing in the recommended LPP is limited to the Federal share of the FCP and the non-Federal sponsor would be required to provide 100 percent of the additional costs associated with design and construction of the LPP. The flood risk management features have an estimated first cost of $1,745,033,000, with the Federal and non-Federal shares estimated at $783,384,000 and $961,649,000, respectively. The recreation features have an estimated first cost of $36,315,000, with the Federal and non-Federal shares estimated at $18,157,500 and $18,157,500 respectively. Thus, the overall Federal share of the first costs of the LPP, including recreation, is estimated at $801,542,000, and the non-Federal share is estimated at $979,806,000. The cost includes $17,600,000 for environmental monitoring and adaptive management. The cities of Fargo, North Dakota and Moorhead, Minnesota are the

non-Federal cost sharing sponsors for the recommended plan. The cities of Fargo and Moorhead would be responsible for the operation, maintenance, repair, replacement, and rehabilitation (OMRR&R) of the project after construction, a cost currently estimated at $3,631,000 per year. The OMRR&R estimate includes $527,135 for monitoring and adaptive management beyond the construction phase.

6. Based on a 4.0-percent discount rate, October 2011 price levels and a 50-year period of analysis, the total equivalent average annual costs of the recommended LPP, including OMRR&R, are estimated to be $99,952,000, including $98,098,000 for flood risk management and $1,854,000 for recreation. The recommended LPP would significantly reduce risk to the Fargo-Moorhead metropolitan area from a flood which has a 1-percent chance of occurrence in any year; the 1-percent chance stage would be reduced from approximately 42.4 feet to 30.6 feet on the Fargo gage, which would require only minimal emergency measures to pass safely. The recommended LPP would leave average annual residual damages estimated at $32,000,000. The equivalent average annual benefits are estimated to be $174,617,000 for flood risk management and $5,130,000 for recreation, respectively. The net average annual benefits would be $76,519,000 for flood risk management and $3,276,000 for recreation, respectively. The benefit-to-cost ratio for flood risk reduction is 1.78 to 1; and the benefit- to-cost ratio for recreation is 2.77 to 1; and the overall project benefit-to-cost ratio is 1.8 to 1.

7. The project would modify three existing Federal projects: the Rush River Channel Improvement project authorized by the Flood Control Acts of 1948 and 1950; the Lower Rush River Channel Improvement project authorized under provisions of Section 205 of the 1948 Flood Control Act; and the Sheyenne River project authorized by the 1986 Water Resources Development Act. The modifications to these projects will not impact the purposes for which they were authorized or the benefits they currently provide, and in some cases will curtail or eliminate the need for their continued operation and maintenance. All modifications will be carried out in a manner that fulfills the authorized purposes and provides the intended benefits of existing projects as well as the recommended plan. For example, approximately 2.1 miles of the Rush River project and 3.4 miles of the Lower Rush River project between the diversion channel and their respective confluences with the Sheyenne River, while no longer necessary to reduce flood risk in the same manner as when they were originally constructed, would continue to convey local drainage and need some measure of maintenance. The Horace to West Fargo portion of the existing Sheyenne River Diversion project would be incorporated into the LPP.

8. The recommended LPP was developed in coordination and consultation with various Federal, State and local agencies using a systems approach in formulating flood risk management solutions and in evaluating the impacts and benefits of those solutions. Study formulation looked at a wide range of structural and non-structural alternatives.

CECW-MVD (1105-2-10a)
SUBJECT: Fargo-Moorhead Metropolitan Area Flood Risk Management Project, North Dakota and Minnesota

9. The non-Federal sponsors wish to perform design and construction of structural flood risk management measures that are elements of the recommended plan. Pursuant to Section 221 of the Flood Control Act of 1970 as amended, and in accordance with existing guidance governing in-kind contribution credit, the non-Federal sponsors will be eligible to receive credit for the work, not to exceed their share, subject to a determination by the Secretary of the Army that the work is integral to the project. Prior to the work being carried out by the non-Federal sponsors, an In-Kind Memorandum of Understanding must be executed between the Corps and the non-Federal sponsors.

10. In accordance with the Engineering Circular on review of decision documents, all technical, engineering and scientific work underwent an open, dynamic and rigorous review process to ensure technical quality. This included an independent Agency Technical Review (ATR), an Independent External Peer Review (IEPR), and a Corps Headquarters policy and legal review. All concerns of the ATR have been addressed and incorporated into the report. The IEPR was conducted by the Battelle Memorial Institute. IEPR of the draft report was completed on July 6, 2010. A total of 23 comments were generated; all were resolved to the satisfaction of the IEPR panel. A second IEPR review began on April 21, 2011 to assess the Supplemental Draft Feasibility Report and EIS and supporting analyses. The IEPR report was completed in July 2011. A total of 16 comments were documented, one was flagged as high, eleven were flagged as medium, and four were flagged as low significance. The comment of high significance addressed the potential risks associated with the operation of the gates at the diversion control structures and the need for redundancy. In response, the Corps will conduct additional hydraulic modeling in the design phase to address the issue and ensure that all structures are designed to be safe and meet all Corps criteria. All other comments from this review have been addressed and incorporated into the final project documents and recommendation as appropriate. Type II IEPR for Safety Assurance will be conducted during the Preconstruction Engineering and Design phase and throughout implementation.

11. I concur with the findings, conclusions, and recommendations of the reporting officers. Accordingly, I recommend that the Fargo-Moorhead project be authorized in accordance with the reporting officers' recommended plan at an estimated flood risk management cost of $1,745,033,000 and estimated recreation cost of $36,315,000 for an overall cost of $1,781,348,000 with such modifications as in the discretion of the Chief of Engineers may be advisable. My recommendation is subject to cost sharing, financing, and other applicable requirements of Federal and State laws and policies, including Section 103 of WRDA 1986, as amended by Section 202 of WRDA 1996. Accordingly, the non-Federal sponsors must agree with the following requirements prior to project implementation.

a. Provide a minimum of 35 percent, but not to exceed 50 percent of total FCP flood risk management costs as further specified below:

(1) Provide the non-Federal share of design costs allocated by the Government to flood risk management in accordance with the terms of a design agreement entered into prior to commencement of design work for the flood risk management features;

(2) Provide, during construction, a contribution of funds equal to 5 percent of total FCP flood risk management costs;

(3) Provide all lands, easements, and rights-of-way, including those required for relocations, the borrowing of material, and the disposal of dredged or excavated material; perform or ensure the performance of all relocations; and construct all improvements required on lands, easements, and rights-of-way to enable the disposal of dredged or excavated material all as determined by the Government to be required or to be necessary for the construction, operation, and maintenance of the flood risk management features;

(4) Provide, during construction, any additional funds necessary to make its total contribution for flood risk management equal to at least 35 percent of total FCP flood risk management costs;

(5) Provide 100 percent of all incremental costs of the Locally Preferred Plan.

b. Provide 50 percent of total recreation costs as further specified below:

(1) Provide the non-Federal share of design costs allocated by the Government to recreation in accordance with the terms of a design agreement entered into prior to commencement of design work for the recreation features;

(2) Provide all lands, easements, and rights-of-way, including those required for relocations, the borrowing of material, and the disposal of dredged or excavated material; perform or ensure the performance of all relocations; and construct all improvements required on lands, easements, and rights-of-way to enable the disposal of dredged or excavated material all as determined by the Government to be required or to be necessary for the construction, operation, and maintenance of the recreation features;

(3) Provide, during construction, any additional funds necessary to make its total contribution for recreation equal to 50 percent of total recreation costs;

(4) Provide, during construction, 100 percent of the total recreation costs that exceed an amount equal to 10 percent of the Federal share of total FCP flood risk management costs;

c. Shall not use funds from other Federal programs, including any non-Federal contribution required as a matching share therefore, to meet any of the non-federal obligations for the project unless the Federal agency providing the Federal portion of such funds verifies in writing that expenditure of such funds for such purpose is authorized;

d. Not less than once each year, inform affected interests of the extent of protection afforded by the flood risk management features;

e. Agree to participate in and comply with applicable Federal floodplain management and flood insurance programs;

f. Comply with Section 402 of the Water Resources Development Act of 1986, as amended (33 U.S.C. 701b-12), which requires a non-Federal interest to prepare a floodplain management plan within one year after the date of signing a project cooperation agreement, and to implement such plan not later than one year after completion of construction of the flood risk management features;

g. Publicize floodplain information in the area concerned and provide this information to zoning and other regulatory agencies for their use in adopting regulations, or taking other actions, to prevent unwise future development and to ensure compatibility with protection levels provided by the flood risk management features;

h. Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) such as any new developments on project lands, easements, and rights-of-way or the addition of facilities which might reduce the level of protection the flood risk management features afford, hinder operation and maintenance of the project, or interfere with the project's proper function;

i. Keep the recreation features, and access roads, parking areas, and other associated public use facilities, open and available to all on equal terms;

j. Comply with all applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended (42 U.S.C. 4601-4655), and the Uniform Regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way required for construction, operation, and maintenance of the project, including those necessary for relocations, the borrowing of materials, or the disposal of dredged or excavated material; and inform all affected persons of applicable benefits, policies, and procedures in connection with said Act;

k. For so long as the project remains authorized, operate, maintain, repair, rehabilitate, and replace the project, or functional portions of the project, including any mitigation features, at no cost to the Federal Government, in a manner compatible with the project's authorized purposes and in accordance with applicable Federal and State laws and regulations and any specific directions prescribed by the Federal Government;

l. Give the Federal Government a right to enter, at reasonable times and in a reasonable manner, upon property that the non-Federal sponsor owns or controls for access to the project for the purpose of completing, inspecting, operating, maintaining, repairing, rehabilitating, or replacing the project;

m. Hold and save the United States free from all damages arising from the construction, operation, maintenance, repair, rehabilitation, and replacement of the project and any betterments, except for damages due to the fault or negligence of the United States or its contractors;

n. Keep and maintain books, records, documents, or other evidence pertaining to costs and expenses incurred pursuant to the project, for a minimum of 3 years after completion of the accounting for which such books, records, documents, or other evidence are required, to the extent and in such detail as will properly reflect total project costs, and in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and Local Governments at 32 Code of Federal Regulations (CFR) Section 33.20;

o. Comply with all applicable Federal and State laws and regulations, including, but not limited to: Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 U.S.C. 2000d) and Department of Defense Directive 5500.11 issued pursuant thereto; Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army"; and all applicable Federal labor standards requirements including, but not limited to, 40 U.S.C. 3141- 3148 and 40 U.S.C. 3701 – 3708 (revising, codifying and enacting without substantial change the provisions of the Davis-Bacon Act (formerly 40 U.S.C. 276a *et seq.*), the Contract Work Hours and Safety Standards Act (formerly 40 U.S.C. 327 *et seq.*), and the Copeland Anti-Kickback Act (formerly 40 U.S.C. 276c *et seq.*);

p. Perform, or ensure performance of, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Public Law 96-510, as amended (42 U.S.C. 9601-9675), that may exist in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project. However, for lands that the Federal Government determines to be subject to the navigation servitude, only the Federal Government shall perform such investigations unless the Federal Government provides the non-Federal sponsors with prior specific written direction, in which case the non-Federal sponsors shall perform such investigations in accordance with such written direction;

q. Assume, as between the Federal Government and the non-Federal sponsors, complete financial responsibility for all necessary cleanup and response costs of any hazardous substances regulated under CERCLA that are located in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project;

r. Agree, as between the Federal Government and the non-Federal sponsors, that the non-federal sponsors shall be considered the operator of the project for the purpose of CERCLA liability, and to the maximum extent practicable, operate, maintain, repair, rehabilitate, and replace the project in a manner that will not cause liability to arise under CERCLA; and

s. Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended (42 U.S.C. 1962d-5b), and Section 103(j) of the Water Resources Development Act of 1986, Public Law 99-662, as amended (33 U.S.C. 2213(j)), which provides that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until each non-Federal interest has entered into a written agreement to furnish its required cooperation for the project or separable element.

12. The recommendation contained herein reflects the information available at this time and current departmental policies governing formulation of individual projects. It does not reflect program and budgeting priorities inherent in the formulation of a national civil works construction program or the perspective of higher review levels within the executive branch. Consequently, the recommendation may be modified before it is transmitted to the Congress as a proposal for authorization and implementation funding. However, prior to transmittal to Congress, the sponsors, the States, interested Federal agencies, and other parties will be advised of any significant modifications and will be afforded an opportunity to comment further.

Merdith W. B. Temple

MERDITH W. B. TEMPLE
Major General, U.S. Army
Acting Chief of Engineers

RECORD OF DECISION

FARGO-MOORHEAD METROPOLITAN AREA
FLOOD RISK MANAGEMENT PROJECT
NORTH DAKOTA AND MINNESOTA

The Integrated Final Feasibility Report and the Final Environmental Impact Statement (FR/FEIS) dated July 2011 and the report of the Chief of Engineers, dated December 19, 2011, address flood risk management in the Fargo-Moorhead Metropolitan Area, North Dakota and Minnesota. Based on these reports, the views of other Federal, State and local agencies, input from the public, and the review by my staff, I find the Fargo-Moorhead Metropolitan Area Flood Risk Management Project, recommended by the Chief of Engineers to be technically feasible, economically justified, in accordance with environmental statutes, and in the public interest. Thus, I approve the Fargo-Moorhead Metropolitan Area Flood Risk Management Project for construction.

The FR/FEIS evaluated a number of non-structural and structural alternatives to reduce flood risk along the Red River of the North, which forms the state boundary in the Fargo-Moorhead Metropolitan Area. The plan selected for implementation is the North Dakota 20,000 cubic feet per second (cfs) diversion channel with upstream storage and staging. The recommended plan is the Locally Preferred Plan (LPP) and consists of the following features:

- Construction of a 36-mile long diversion channel;
- Construction of water control structures on the Red River of the North and the Wild Rice River;
- Construction of 2 aqueduct tributary structures—one on the Sheyenne River and one on the Maple River;
- Construction of 2 tributary drop structures, 1 tributary control structure, a diversion inlet structure, 19 highway bridges, 4 railroad bridges and other appurtenant facilities, such as drop structures and debris handling facilities;
- Implementation of non-structural measures within the defined storage area and staging area, including acquisition of fee title or flowage easements and construction of community and individual ring levees;
- Construction of recreation features including but not limited to multipurpose trails, restrooms, potable water, picnic facilities, parking areas, and landscaping and tree plantings;
- Construction of 398 acres of mitigation measures including floodplain forest and wetland habitats, stream restoration and fish passage structures in the Red and Wild Rice river basins;
- Implementation of a monitoring and adaptive management plan to ensure mitigation success; and

- Construction of approximately 10 miles of tie-back levees and construction of approximately 12 miles of storage area embankments to address hydraulic impacts.

In addition to the no-action plan, several conceptual flood risk management alternatives were identified and evaluated, including non-structural measures, improved flood conveyance, flood barrier systems and flood storage. Three action alternatives were included in the final array of alternatives in the FR/FEIS which is incorporated herein by reference. The alternatives consisted of various sizes and locations of floodway channels and associated elements to temporarily convey flood flows around the Fargo-Moorhead metropolitan area. The LPP provides the best combination of flood risk management benefits while meeting the project purpose and needs of local stakeholders. All practicable means to avoid or minimize adverse environmental effects have been incorporated into the project. Compensatory mitigation measures are included in the project to address unavoidable impacts.

The environmentally preferable plan is the Minnesota diversion channel conveying 35,000 cfs. It has fewer impacts to wetlands, tributaries and fish passage when compared to the other alternatives in the final array of alternatives. It was not selected because it did not address flooding from all five of the tributaries in the metropolitan area, which was a desired outcome of the non-Federal sponsors.

Technical and economic criteria used in the formulation of alternative plans were those specified in the Water Resource Council's Economic and Environmental Principles and Guidelines for Water and Related Land Resource Implementation Studies. All applicable laws, executive orders, regulations and guidelines were considered in the evaluation of alternatives and the selection of the recommended plan. Based on review of these evaluations, I find that the overall flood risk management benefits gained with construction of the recommended project serve the public interest and outweigh any adverse effects. This Record of Decision completes the National Environmental Policy Act process.

APR - 3 2012
Date

Jo-Ellen Darcy
Jo-Ellen Darcy
Assistant Secretary of the Army
(Civil Works)

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

March 28, 2012

The Honorable Jo Ellen Darcy
Assistant Secretary of the Army (Civil Works)
108 Army Pentagon
Washington, DC 20310-0108

Dear Ms. Darcy:

As required by Executive Order 12322, the Office of Management and Budget completed its review of your recommendation for the Fargo-Moorhead Flood Risk Management and Recreation Project, North Dakota and Minnesota. Based on our review, we conclude that your recommendation for authorization of construction of this project is consistent with the policy and programs of the President.

The Office of Management and Budget does not object to you submitting this report to Congress. When you do so, please advise the Congress that, should the Congress authorize the project for construction, the project would need to compete with other proposed investments in future budgets.

Sincerely,

Richard A. Mertens
Deputy Associate Director
Energy, Science, and Water

202-761-0050

Enclosure 3

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

TAKE PRIDE IN AMERICA

OCT 24 2011

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Mr. Theodore A. Brown, P.E.
Chief, Planning and Policy Division
Directorate of Civil Works
Headquarters
U.S. Army Corps of Engineers
CECW-P (SA)
7701 Telegraph Road
Alexandria, VA 22315-3860

RE: Final Feasibility Report and Environmental Impact Statement, Fargo-Moorhead Metropolitan Area Flood Risk Management, Cass and Richland Counties, North Dakota and Clay and Wilkins Counties, Minnesota

Dear Mr. Brown:

The U.S. Department of the Interior (Department) has reviewed the U.S. Army Corps of Engineers (Corps), Chief of Engineers Report, and the Final Feasibility Report and Environmental Impact Statement for the Fargo-Moorhead Metropolitan Area Flood Risk Management Project, Cass and Richland Counties, North Dakota, and Clay and Wilkins Counties, Minnesota. We offer the following comments and recommendations based upon the jurisdiction or special expertise of our U.S. Fish and Wildlife Service (FWS).

GENERAL COMMENTS

The FWS is authorized under the Fish and Wildlife Coordination Act (16 U.S.C. 661 et seq.) to provide recommendations to the Corps on federally funded water development projects. Based on information available at this time and the impact analysis outlined in the Final Fish and Wildlife Coordination Act Report (July 2011), the FWS recommends that, should the Corps and the local project sponsors proceed with the Fargo-Moorhead Metropolitan Flood Risk Reduction Project, the Federally Comparable Plan (FCP or MN 35K Alternative) Diversion Channel Alternative be the selected Alternative.

Adverse ecological impacts will occur with any of the Diversion Channel Alternatives. For the following reason, however, the FCP Alternative would result in less severe ecological impacts than the Locally Preferred Plan (LPP) Diversion Channel Alternative:

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1. The LPP Alternative is anticipated to adversely impact approximately 189 more acres of wetland then the FCP Alternative;
2. The LPP Alternative, as proposed, would result in 36 more acres of adverse impacts to aquatic habitat then the FCP Alternative;
3. The LPP Alternative would adversely impact 5 rivers in addition to the main stem of the Red River;
4. The LPP Alternative, as proposed, would result in 110.3 more acres of adverse impacts to forest habitat then the FCP Alternative; and
5. Apart from the work that would occur within the Red River and the adjacent riparian habitat, the land uses that would be primarily affected by the FCP Alternative have limited wildlife habitat value.

For a complete list of FWS recommendations please refer to the FWS' Final Fish and Wildlife Coordination Act Report (attachment 2 within the Corps Final Feasibility Report and Environmental Impact Statement). The report is also enclosed for your convenience.

We appreciate the opportunity to provide comments. If you have questions concerning the Departments comments, please contact Tony Sullins, FWS, Field Supervisor, Twin Cities Ecological Services Field Office at 612-725-3548, extension 2201, or email Tony_Sullins@fws.gov.

Sincerely,

Willie R. Taylor

Willie R. Taylor
Director, Office of Environmental Policy
and Compliance

Enclosure

DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS
441 G STREET, NW
WASHINGTON, DC 20314-1000

REPLY TO
ATTENTION OF

Mississippi Valley Division
Regional Integration Team

DEC 22 2011

Mr. Willie R. Taylor
Director, Office on Environmental Policy and Compliance
U.S. Department of the Interior
1849 C Street, Mail Stop 2342
Washington, D.C. 20240

Dear Mr. Taylor:

This is in response to the U.S. Department of Interior (DOI) letter, dated October 24, 2011, commenting on the Final Feasibility Report and Environmental Impact Statement for the Fargo-Moorhead Metropolitan Area Flood Risk Management Project (FEIS) and the Proposed Chief of Engineers Report. The DOI recommended that the Federally Comparable Plan (FCP) described in the FEIS be identified as the recommended plan.

As described in the FEIS, the FCP does not achieve the project objective of reducing flood risk and flood damages to the same degree as the Locally Preferred Plan (LPP), the North Dakota diversion with upstream storage and staging. During the course of the planning process, it became evident that local stakeholders strongly desired measures to reduce flood risk for the entire Metropolitan area, including the risks from the Red River of the North, as well as the Sheyenne, Wild Rice (ND), Maple, Rush, and Lower Rush rivers. The LPP provides flood stage reductions to a greater geographic area and for approximately 6,250 additional citizens than does the FCP. It achieves this result by reducing flood risk from the Sheyenne River and its tributaries in addition to the Wild Rice (ND) and Red rivers. This added level of risk reduction is not available from the FCP. Therefore, the FCP does not achieve the sponsors' objective of reducing flood risk from both the Red River and the five North Dakota tributaries.

Thank you for your interest and input to the review of this Corps Civil Works study.

Sincerely,

Theodore A. Brown, P.E.
Chief, Planning and Policy Division
Directorate of Civil Works

Enclosure 5

State of
North Dakota
Office of the Governor

Jack Dalrymple
Governor

November 7, 2011

Headquarters, U.S. Army Corps of Engineers
ATTN: CECW-P (IP)
7701 Telegraph Road
Alexandria, VA 22315-3860

RE: Comments on the Fargo-Moorhead Metropolitan Area Flood Risk Management Project Final EIS (FEIS) and Proposed Report of the Chief of Engineers

Dear U.S. Army Corps of Engineers, Headquarters:

This letter is submitted as my comments on the Fargo-Moorhead Metropolitan Area Flood Risk Management Project FEIS and Proposed Report of the Chief of Engineers.

Since the Fargo-Moorhead Metropolitan Area Flood Risk Management Study was authorized, the State of North Dakota has attended Metro Working Group meetings, meetings with local sponsors and meetings with concerned stakeholders that are directly and indirectly affected by the proposed project. In September I had the opportunity to attend the Civil Work Review Board Hearing held in Washington DC, along with the local sponsors. While the state has been carefully monitoring this process, it is important to note that the state is serving a support role in the effort to develop a flood protection plan. Local governing entities, their constituents and the U.S. Army Corps of Engineers will determine the project's scope and footprint.

The plan selected as most feasible in the FEIS, the Locally Preferred Plan, consists of a 36-mile long channel with a capacity of 20,000 cubic feet/second (cfs), including upstream staging and storing channel. This plan, which was proposed by Fargo and Cass County officials, would not only affect stakeholders in the Fargo-Moorhead metropolitan area, but would also affect upstream and downstream stakeholders as well. To ensure the interests of all stakeholders are considered, I request that the U.S. Army Corps of Engineers carefully consider all comments submitted regarding the FEIS when selecting and implementing a final flood protection plan for the Fargo-Moorhead Metropolitan area.

600 E Boulevard Ave. • Bismarck, ND 58505-0001 • Phone: 701.328.2200 • Fax: 701.328.2205 • www.governor.nd.gov

Enclosure 6

Headquarters, U.S. Army Corps of Engineers
November 7, 2011
Page 2

To support the effort to reach a long-term solution regarding flood risk and damage in the Fargo-Moorhead area, the State of North Dakota is committed to providing funding to cover one half of the non-federal, non-Minnesota share of the project's costs. Aside from providing funding, the State of North Dakota will continually monitor the process as the Corps and local sponsors proceed with the design, survey, and construction phases of the project.

Thank you for your consideration and for the opportunity to comment on the Fargo-Moorhead Metropolitan Area Flood Risk Management Project Final EIS and Proposed Report of the Chief of Engineers. I appreciate the work the U.S. Army Corps of Engineers has done with local level stakeholders to identify and construct the optimal flood protection plan.

Sincerely,

Jack Dalrymple

Jack Dalrymple
Governor

37:68:56

Minnesota Department of Natural Resources

Regional Operations
2115 Birchmont Beach Rd NE
Bemidji, MN 56601
218.308.2629

November 4, 2011

Aaron Snyder
USACE Project Manager
190 East 5th Street
Suite 401
St. Paul, MN 55101

RE: Minnesota Department of Natural Resources (DNR) Comments
Fargo Moorhead Final Feasibility Report and Environmental Impact Statement (FEIS)

Dear Mr. Snyder,

The State of Minnesota remains committed to flood protection in the Red River valley and appreciates the opportunity to review the FEIS. Based on our review of the FEIS, it's still apparent that additional work is needed to demonstrate that the selected alternative is:

- ecologically sustainable,
- the least impact solution,
- one in which adverse effects can and will be mitigated, and
- consistent with other standards, ordinances, and resource plans of federal, local and regional governments.

The locally preferred plan includes a water control structure that is classified as a high hazard dam, which requires preparation of Minnesota State EIS. As part of State EIS scoping, additional assessment and review will be necessary to demonstrate that the above mentioned criteria are fulfilled. This letter provides insight on the types of issues that must be addressed as part of state environmental review and permitting.

Portions of past DNR correspondence remain relevant as key concerns are not addressed. DNR comment topics remain consistent with past correspondence. In the interest of brevity, DNR comments on the FEIS will reference past comments when appropriate. Referenced comments should be considered part of DNR's FEIS comments.

<u>Attachments:</u>

1. DNR DEIS comments - August 6th, 2010
2. DNR SDEIS Scoping Comments – January 24, 2011
3. DNR SDEIS Comments – June 16, 2011

Enclosure 7

For each topic, general, and in some cases, specific comments (which reference specific areas in the FEIS) are provided. The DNR offers the following comments:

Scope of Alternatives

General Comments:
The alternative analysis and screening conducted as part of the federal EIS has been a significant source of concern and has received many comments from the public and agencies (DNR included). Review of Appendix O has generated several questions around the cost benefit analysis and alternative screening. As part of State EIS scoping the MDNR needs to verify and document the information that was used in the various phases of the federal EIS. In order to complete the MDNR's administrative record for the State EIS, we will need an independent review and documentation of the key decision steps and the information that was used to make the decisions. This detailed review and documentation will either confirm selection of alternatives in the federal FEIS or identify other alternatives that should be evaluated as part of the State EIS.

Specific Comments:

Magnitude of Flood Risk Reduction
Appendix U response to comments addresses the level of flood risk reduction in response to comment A-15. This response indicates that the level of flood risk reduction was a goal of a 36 feet stage at the Fargo gage for a 0.2% chance event (500 year flood) that had been identified by the Metro Flood Study Workgroup (MFSWG) and that minutes from the MFSWG are in Appendix Q.

Minnesota Rules part 4410.2300 subpart G provides the content requirements for Minnesota State EISs as it relates to alternatives. One of the alternatives that needs to be evaluated is a modified scale or magnitude. The magnitude of flood risk reduction is appropriate for alternative analysis. The specific level of flood risk reduction that is selected as meeting the project purpose is critical to alternative screening and alternative analysis. After reviewing the MFSWG minutes it is still unclear how the 500 year flood protection was determined to meet the purpose of the project. There are statements that indicate a desire for more than 100 year flood protection and that 500 year flood protection would protect a much greater area. There is also a mention of county planning for flood elevation of 36 feet. Presumably there are criteria or rationale that was used by the MFSWG to set the goal of protecting the metro area at a 36 foot stage for 0.2% chance flood events. However, this information was unattainable from the meeting minutes as was suggested by the response to comment A-15.

Additionally, it is unclear how the MFSWG determined the locally preferred plan (LPP) that does not meet the MFSWG goal was still an acceptable level of flood protection. The discussion indicates flood fighting techniques could be used during those floods that have a stage over 36 feet at the Fargo gage. It appears that the flood elevation when at a stage of 36 feet is a critical flood elevation for protection efforts. Documentation of the information that led to this decision is needed as part of the State EIS process.

As was indicated in our comments on the SDEIS, the MDNR is concerned that viable alternatives for flood protection were screened out because the magnitude of the flood risk reduction goal was too large. As part the Minnesota State EIS Scoping the MDNR will need a record of explicit factors that were considered by the MFSWG and how those factors lead to the 500 year flood protection goal.

Control Structures

Response to comment A-22 indicates that incremental measures such as small levees and non-structural measures do not have a synergistic effect with the proposed diversion; as such, the diversion without control structures is not a feasible alternative even with the incremental measures in place. The response indicates a diversion without control structures is marginally feasible at best and a diversion without control structures is less efficient regardless of other incremental measures in place.

Phase 1 evaluated diversions without control structures and found that they were very effective at decreasing flood stages but not cost effective. Phase 2 screening #1 found the addition of the control structure drastically improved performance with a modest increase in cost. Both of the cost benefit analyses for these conclusions need verification as part of the State EIS scoping. The control structure has the potential for significant environmental effects so the DNR must assure that there are no other feasible and prudent alternatives.

Passing Additional Flow through Fargo-Moorhead

The FEIS provides brief mention of the possibility of passing additional water through the Fargo-Moorhead area at flows above 9,600 cfs at Fargo. It is unclear why it is a possibility to allow additional water through town as a mitigation measure, yet this alternative wasn't carried forward as a project alternative. It seems that inclusion of such a measure could significantly minimize a variety of impacts and still meet the project purpose. Since MN can only permit a least impact solution, the State EIS scoping and permitting will need to fully explore this alternative. It is unclear how this incremental measure was deemed appropriate as mitigation given the response to comment A-22 that indicated no synergistic effect between levees and diversion channels was found.

Future Development

Response to comment A-22 indicates development within flood prone areas is restricted by city floodplain ordinances based on FEMA maps. The future development in the study area is assumed to be in compliance with local city floodplain ordinances. Development will need to comply with existing floodplain maps and ordinances until a FEMA Letter of Map Revision is approved.

It is unclear how future development in flood prone areas was treated in the federal process. The response assumes compliance with flood protection land use regulations, but yet there is still a problem. How and why are the land use regulations failing (development prior to regulations, greater magnitude floods that are not addressed by regulation, etc.)? There may be an opportunity to look creatively at land use controls that help reduce flood risk if the current regulations leave an unacceptable level of risk.

The use of future development in (previous) flood prone areas as project benefit seems to drive up the cost benefit ratio for projects that protect the largest land base. We need a better understanding of the how the benefits from developing formerly flood prone areas were calculated in the cost benefit analysis.

Alternative Screening Criteria

The Corps identified a broad set of screening criteria that were used as part of alternative screening. We need a clear idea of how these criteria were applied to each alternative. We need to fully understand the application of the criteria used in the federal EIS and develop the criteria we will use as part of alternative screening in the State EIS.

Hydrology

In responding to DNR comments requesting that if used, the wet-dry analysis should be submitted to FEMA for review and acceptance, the Corps responded, "*The Corps has been working closely with FEMA, the State of Minnesota, and the State of North Dakota to ensure that the project as proposed will be provided with a CLOMR. The proposed mitigation should be sufficient to comply with all current regulations. The Corps will continue to coordinate with the agencies as this project progresses.*" It is our understanding that FEMA and the Corps are developing a Memorandum of Understanding regarding the CLOMR. Review of the wet-dry analysis should be included in the MOU.

Floodplain Hydraulics

DNR's comments requested the FEIS describe compatibility with all land use controls and that costs for all mitigation and for development without the CLOMR be included in the economic analysis.

A description of local, state and federal floodplain requirements along with plan compatibility and consistency should be well articulated for a flood damage reduction project. Instead, the main text of the FEIS contains no mention of the CLOMR process, compatibilities with land use regulations and steps needed to address those incompatibilities. Instead, the Appendix U containing responses to comments indicates, "*The Corps has been working closely with FEMA, the State of Minnesota, and the State of North Dakota to ensure that the project as proposed will be provided with a CLOMR. The proposed mitigation should be sufficient to comply with all current regulations. The Corps will continue to coordinate with the agencies as this project progresses.*"

Section 3.8.3.4.2 indicates that there is no federal requirement for mitigation. It's our understanding that FEMA does require mitigation to existing buildings and will have mitigation requirements beyond what can be reimbursed by the Corps as determined by the takings analysis. It remains unclear whether all of these costs were included in the cost benefit analysis.

The State EIS will need to fully describe project consistency and compatibility with all applicable land use controls. All mitigation costs and costs for development without the CLOMR should be included in the economic analysis. Specifics about the types of mitigation and who will pay for it will also be required for State permitting.

Geomorphology

DNR's geomorphology comments on the FEIS contained herein focus on the locally preferred plan (LPP). With exception to providing additional sediment data, DNR comments in the FEIS regarding other alternatives remain relevant and are attached.

General Comments:
Overall the FEIS continues to drastically discount the potential for impacts caused by changes in geomorphic processes. Furthermore, DNR's direct observations of major sedimentation along the Red River following large flood events contradict many of the estimates and conclusions in the FEIS. It will be necessary for the State EIS to fully disclose both the likelihood and the significance of these impacts.

Specific Comments:

Upstream Sedimentation

Corps response to comments indicates, "*If the conservative estimate presented in the FEIS (conservative because it is assumed that all incoming sediment from upstream would settle in the flood pool) would be off by one to two orders of magnitude in some localized areas, the sedimentation rates in such areas would be 2-3 inches, which is well within the expected range of sedimentation driven by natural processes during large flood events in a complex riverine system where sediment transport is dominated by very fine material (silts and clays) mobilized in suspension.*" As referenced in our SDEIS comments, DNR has frequently witnessed 2 feet or more of sediment deposition in non-reservoir areas. Furthermore, comparisons to Christine and Hickson are not appropriate. Both of these dams inundate at bankfull and have higher flows resulting in reservoir stages, slopes, and shear stress values that are the same as they would be if the dams were not there. The proposed dam and reservoir would not be inundated during 5 year and larger floods. As noted, velocities in the reservoir would be very low as would shear stress leading to sediment deposition. Sedimentation rates of 2-3 inches are very substantial especially when put in the context of cumulative effects.

Within the FEIS, sedimentation impacts for Wolverton creek are included within the general description of effects of upstream staging. Since the LPP includes complete blockage of flows on Wolverton Creek; a separate discussion for this resource is warranted.

As part of the State EIS scoping, full disclosure must be given to potentially significant geomorphic impacts. Decreasing operational frequency and staging duration – a possibility mentioned in the FEIS - would help to minimize impacts and should be further explored.

Downstream Geomorphology

DNR agrees that the Red River is currently very stable in its form and, depending on the operation plan, a diversion by itself may not have substantial effects on downstream geomorphology. However, with the addition of a dam and prolonged discharge of high flows there are additional concerns. There would be some potential for channel enlargement due to the increased duration and frequency of bankfull and higher events from the prolonged discharge of water from the dam reservoir. Since channels forming flows are a function of the product of sediment transport rate and flow frequency, changes to either could have adverse consequences for riparian vegetation, channel stability, sediment, and habitat.

Bank Stability

The FEIS continues to provide little substantiation for the assertion that, "stability of a larger portion of the lower bank and the upper bank would not likely be affected by a small increase in duration of bankfull conditions".

The DNR maintains that exacerbation of bank failures can be expected under the LPP (as described in the FEIS). Bank erosion problems are likely to be exacerbated by several factors associated with the new dam including:

- As sediments accrete in the floodplain (reservoir), bank heights will increase, loading the banks, and increasing potential for slumping as the reservoir is drained.

- Stability of the Red River channel is heavily dependent on riparian trees which provide mechanical strength due to roots and draw moisture from the soils increasing soil critical shear stress. Removal of riparian trees has consistently resulted in bank slumping while these slumps are relatively rare where the riparian zone is intact. Trees along the Red River are already stressed during prolonged floods and can suffer root rot that can kill younger trees in particular. This reservoir would damage the riparian corridor by creating a reservoir that would hold water higher and longer, killing riparian trees. Once dead, the trees will no longer perform the bank stabilization functions.

- Soil saturation is a major factor in bank slumping along the Red River. The reservoir will increase soil saturation by holding water higher and longer. Draining of the reservoir will also result in more sudden changes in water level in the channel; a factor frequently associated with slumping. When the reservoir is drained, these weakened soils will be prone to collapse.

- Large slumps can fill a significant proportion of the cross-sectional area of the channel. This reduced flow capacity through the cross-section results in higher upstream stage, higher velocities, and higher shear stress causing additional erosion until the cross-sectional area is regained.

A significant reduction in the frequency of operation and staging duration through design features which pass additional flows through town would greatly minimize these impacts. Since the adaptive management remedies for this condition are limited to either changing operating procedures of the dam (which would tend to defeat its purpose), or the development of a fully wooded riparian corridor (prolonged inundation of the existing wooded corridor may actually worsen conditions and limit the development of a woody corridor where none exists), impact minimization through design changes should occur upfront.

Fish Passage and Biological Connectivity

DNR acknowledges the merits of the additional fish passage channels around the Red River structure. These additional features (i.e. up to 8 fish passage channels) along with inclusion of the option of passing more water through the metro, if implemented, will go a long way in minimizing both biological connectivity and geomorphologic impacts.

DNR concerns - as stated in past comments - that fish passage should be provided through the diversion channel remains unchanged. Further, we ask that the Corps support their conclusion contained in Appendix U which states, "*... this cost would not be justified by the number of fish expected to reach the upper end of the diversion.*"

DNR concerns regarding potential impacts caused by reduced fish passage and impacts to channel morphology caused by impounding water on Wolverton Creek remain unchanged. We believe it is insufficient to address these concerns by stating, *"It is unclear if this impact is substantial enough to warrant additional mitigation beyond what has already been proposed in the FEIS"* and we believe a thorough evaluation of the potential impacts is warranted and should be addressed as part of State EIS scoping.

Wetland Impacts

Many of DNR comments pertaining to wetlands have been addressed in the FEIS; however, the FEIS still does not describe whether perpetual easements or other protections will be placed on the replacement site(s). This information was requested as part of DNR's comments on the SDEIS. Such a requirement is consistent with Corps Policy which requires that wetland replacement sites be protected through appropriate real estate instruments such as covenants, conservation easements, or transfer of title to a public natural resource agency or private conservation organization.

DNR also requested that the FEIS provide an analysis of the potential impacts that operation of the alternatives will have on wetlands and that mitigation be provided for all impacts. In responding to this request Appendix U indicates, "*The operation of the project was considered in this analysis; no appreciable impacts to wetlands would occur due to operation of the project.*" It remains unclear how impacts resulting from operation were considered in the FEIS. DNR asks that supplemental information be provided which describes indirect impacts caused by cumulative sedimentation within the reservoir and due to changes in downstream floodplain hydraulics. This information will be required as part of State EIS scoping.

Debris and Ice

DNR's SDEIS comments recommended that the FEIS include a comprehensive study of potential ice and debris impacts of the alternatives. Unfortunately this information was not included in the FEIS. It will be important that project induced ice impacts be assessed during State EIS scoping.

Mitigation and Adaptive Management

DNR's past comments on this topic remain relevant (see attached).

General Comments:
For impacts the Corps is concluding will be less than significant - but still possible - Corps is relying on future monitoring and adaptive management/mitigation. DNR generally agrees with this approach, however; there remains an area which DNR does not agree that impacts will be less than significant and additional minimization of impacts through design changes should be pursued upfront, rather than waiting to see if impacts occur. Specifically, significant geomorphic impacts can be avoided and minimized by reducing the operational frequency.

Regardless of DNR's past comments, to date no assurance that future mitigation action will occur has been provided for potential impacts that will be verified through post operation monitoring. This lack of assurance will provide serious challenges as it relates to state permitting.

A mutually agreed upon mitigation and adaptive management plan containing the specific criteria, indicators, thresholds, response actions, costs, and assurances will be required as part of State EIS Scoping. DNR permits will also include similar mitigation provisions. DNR will continue to work with the Corps, other agencies, and project sponsors in developing a mutually agreeable adaptive management plan; however, the responsibility for plan implementation would be that of a permittee.

State Environmental Review and Permitting

As previously mentioned in our SDEIS comments, in order to comply with statutory requirements associated with Public Waters Permitting (103G) and Environmental Impact Statements (116D); DNR must require that the permit-level analysis be compiled and provided concurrently with the State EIS process. If the sponsor wishes to proceed with a State EIS before permit-level analysis can be provided, the sponsor must contact DNR's Public Waters Work Program to discuss options under which they can consent to exceed new goals for issuing permits.

Conclusion

As outlined in our comments to date, additional efforts are needed to demonstrate that the project is ecologically sustainable, the least impact solution, adverse effects can and will be mitigated, and the chosen project is consistent with other standards, ordinances, and resource plans of federal, local and regional governments. This information will be necessary for both the state environmental review and permitting processes.

Thank you for considering our input.

Sincerely,

Michael R. Carroll
Assistant Commissioner
Mike.carroll@state.mn.us

XXX

cc: DNR Commissioner's Office
Kent Lokkesmoe, Director of Capital Investment
Steve Hirsch, Division of Ecological and Water Resources Director
Red River Watershed Management Board
Red River Basin Commission
City of Moorhead
FEMA Region V
FEMA Region VIII
Denver Federal Center
Building 710, Box 25267
Denver, CO 80225-0267
EPA Region V
EPA Region VIII
Will Seuffert, MN Governor's Office

Note: This copy of the Main Report of Final Feasibility Report and Environmental Impact Statement, Fargo-Moorhead Metropolitan Area Flood Risk Management, Red River of the North, includes the Errata Sheet dated November 2011. In addition, the errata are represented throughout the Report using strikethrough and insert characters.

Final Feasibility Report and Environmental Impact Statement

Fargo-Moorhead Metropolitan Area Flood Risk Management

July 2011
with Errata dated November 2011

US Army Corps of Engineers ®

Prepared by:
U.S. Army Corps of Engineers
St. Paul District
180 Fifth Street East, Suite 700
St. Paul, Minnesota 55101-1678

Errata Sheet
Final Feasibility Report and Environmental Impact Statement
Fargo-Moorhead Metropolitan Area Flood Risk Management
Red River of the North

November 2011

1. Purpose:

This errata sheet corrects and/or clarifies portions of the Final Feasibility Report dated July 2011. The information contained in this errata document supersedes the affected portions of the July 2011 report.

2. Pursuant to comments received in the Office of Water Project Review, the following changes were made to the Main Report:

A. Section 3.5.4.1, page 53, fourth paragraph: first sentence is changed to read: "The Rush and Lower Rush Rivers, which currently consist of constructed trapezoidal channels, would flow into the diversion channel, resulting in reduced flows in the downstream portion of these rivers."

B. Section 3.7.3.4, page 81, third paragraph: delete the sentence reading: "With either alignment the existing Horace to West Fargo diversion would be abandoned."

C. Section 3.11.1.1, page 112, fifth paragraph: fourth sentence is changed to read: "The Rush and Lower Rush Rivers, which currently consist of constructed trapezoidal channels, would be allowed to flow into the diversion channel, resulting in reduced flows in the downstream portion of these rivers."

D. Section 3.11.1.1, page 114, first paragraph: the first sentence is changed to read: "The existing Horace to West Fargo diversion channel would be incorporated into the ND35K alignment."

E. Section 3.13.1.1, page 121, fourth paragraph: the first sentence is changed to read: "The existing Horace to West Fargo diversion channel would be incorporated into the LPP alignment."

F. Section 5.2.1.5.3, page 244, second paragraph: the first sentence is changed to read: "Additional wetland impacts from the LPP and ND35K are possible because flows in the existing channels downstream of the diversion for the Lower Rush River and the Rush River will be reduced."

G. Section 5.2.1.7.1.4, page 261, fourth paragraph: first sentence is changed to read: "The plan for the North Dakota alternatives would result in significantly reduced flow in approximately 2.1 miles of the Rush River, and 3.4 miles of the Lower Rush River, between the diversion channel and their respective confluences with the Sheyenne River."

H. Section 5.2.1.7.1.4, page 261, fourth paragraph: sixth sentence is changed to read: "This habitat would be more abundant, and potentially of better quality, than the habitat affected by reduced flows."

I. Section 5.2.1.7.1.4, page 261, fifth paragraph: first sentence is changed to read: "The affected channels would likely be identified as areas not to be developed in the future."

J. Section 5.5.3.2, page 371, third paragraph: the first sentence is changed to read: "For the ND35K and LPP, the Rush River and Lower Rush River would be redirected to flow into the diversion channel, significantly reducing flows in almost six miles of tributary habitat."

K. Section 5.5.3.2, page 371, fourth paragraph: the first sentence is changed to read: "Monitoring for biotic use would be performed prior to construction within sections of the Rush and Lower Rush rivers proposed for modification."

L. Section 8.0, page 390, third paragraph: the last sentence is changed to read: "The modifications to these projects will not impact the purposes for which they were authorized or the benefits they currently provide, and in some cases will curtail or eliminate the need for their continued operation and maintenance. All modifications will be carried out in a manner that fulfills the authorized purposes and provides the intended benefits of existing projects as well as the recommended plan."

M. Section I, Part C on page 4 of Attachment 1, the last sentence on this page is changed to read: "At the Lower Rush River and Rush River, a stepped concrete spillway will be used to divert the entire flow into the diversion channel, significantly reducing flows in the remaining channel between the diversion channel and the Sheyenne River."

N. Section II, Part H on page 17 of Attachment 1, the third sentence is changed to read: "The Lower Rush River and Rush River will have 5.7 miles of channel with significantly reduced flows which will be maintained as wetland habitat."

3. Pursuant to comments received in the Office of Water Project Review, the following change was made to Appendix O – Plan Formulation: Section 8.4.4.2.4, paragraph 2 on page O-70, delete the third sentence reading: "With either alignment the existing Horace to West Fargo diversion would be abandoned."

4. Pursuant to an Independent External Peer Review comment, the following information is added to Appendix P – Non-Structural, Part 1:

16.0 Nonstructural Flood Proofing Cost Information for Residential Structures

Nonstructural flood risk reduction techniques used for residential structures include elevating the entire structure, elevating the main floor, wet flood proofing, and permanent acquisition (buyout). Additional methods can be combined with

the methods listed above such as filling in basements, and constructing additions to compensate for lost square footage and to house utilities.
To determine the cost for implementation of these measures, the National Nonstructural Flood Proofing Committee (NFPC) obtained costs from several different sources: Omaha District (NWO) Cost Estimating Branch, and the St. Paul District (MVP) Plan Formulation and Economics Branch. Each nonstructural option is listed below along with a description of the costs involved and how the total cost was calculated.

16.0.1 Elevating Entire Structure
The NWO Cost Estimating Branch provided the NFPC with a cost per square foot to raise a structure either 3, 6, 9, or 12 feet in height. A table was created and entered into Microsoft Excel and linear equation was derived for each range of structures. Table 2 contains the equations that were derived in Excel.

16.0.2 Elevation with Dry Flood Proofed Basement
The equations from Table 2 were used to elevate structures based on the vertical distance and square footage of the structure. The cost for the dry flood proofing materials was developed by contacting local hardware suppliers and calculating the individual unit cost and cost per square foot for the sealants and veneer.

16.0.3 Fill Basement with Main Floor Addition
The NWO Cost Estimating Branch provided the NFPC with average costs of fill material per cubic foot. An average depth of 8 feet and the perimeter of the structure was used to calculate the area. The cost for the main floor addition was provided to the NFPC by the NWO Cost Estimating Branch. It is based on an average cost per square foot for construction. (See Table 3 & 4)

16.0.4 Permanent Acquisition (Buyout)
The cost for buying out structures, as shown in Table 10, was calculated by adding the structure value and land value from the County Assessors database and applying a multiplier. The multiplier was based on actual mitigation costs provided by the MVP Plan Formulation and Economics Branch.

16.0.5 Wet Flood Proof
The costs for wet flood proofing were provided by the NFPC. Cost for removing damageable materials and raising utilities is an average cost that was used over a range of structure sizes. Costs for flood vents and installation of the vents were obtained from the flood vent manufacturer. Table 5 contains the cost breakdown.

16.1 Nonstructural Flood Proofing Cost Information for Commercial Structures
Nonstructural flood risk reduction techniques used for commercial structures include dry flood proofing, elevating the entire structure, constructing floodwalls, permanent acquisition (buyout), relocation of structures and wet flood proofing.

These techniques can be combined to include filling basements with a dry flood proofed main floor.
To figure the cost for implementation of these measures, the NFPC obtained costs from several different sources: NWO Cost Estimating Branch, and the MVP Plan Formulation and Economics Branch. Each nonstructural option is listed below along with a description of the costs involved and how the total cost was calculated.

16.1.1 Dry Flood Proofing
The costs for the dry flood proofing materials were developed by contacting local hardware suppliers and calculating the individual unit cost and cost per square foot for the sealants and veneer. Table 7 provides the breakdown of costs involved.

16.1.2 Elevate Entire Structure
The NWO Cost Estimating Branch provided the NFPC with a cost per square foot to raise a structure either 3, 6, 9, or 12 feet in height. A table was created and entered into Microsoft Excel and linear equation was derived for each range of structures. Table 2 contains the equations that were derived in Excel.

16.1.3 Floodwall
The cost for the construction of floodwalls was developed by the NWO Cost Estimating Branch. They gave the NFPC a range of heights above ground for the wall and a cost per linear foot for each. Table 8 contains the costs associated with the various heights.

16.1.4 Fill Basement
The NWO Cost Estimating Branch provided the NFPC with average costs of fill material per cubic foot. An average depth of 8 feet and the perimeter of the structure was used to calculate the area. Table 9 contains the breakdown of the costs to fill basements.

16.1.5 Fill Basement and Dry Flood Proof
The NWO Cost Estimating Branch provided the NFPC with average costs of fill material per cubic foot. An average depth of 8 feet and the perimeter of the structure was used to calculate the area. The costs for the dry flood proofing materials were developed by contacting local hardware suppliers and calculating the individual unit cost and cost per square foot for the sealants and veneer.

16.1.6 Fill Basement and Construct Floodwall
The NWO Cost Estimating Branch provided the NFPC with average costs of fill material per cubic foot. An average depth of 8 feet and the perimeter of the structure was used to calculate the area. The cost for construction of floodwalls was developed by the NWO Cost Estimating Branch. A range of heights above ground for the floodwall and a cost per linear foot was provided.

16.1.7 Permanent Acquisition (Buyout)
The cost for buying out structures, as shown in Table 10, was calculated by adding the structure value and land value from the County Assessors database and applying a multiplier. The multiplier was based on actual mitigation costs provided by the MVP Plan Formulation and Economics Branch.

16.1.8 Wet Flood Proof
The costs for wet flood proofing were provided by the NFPC. Cost for removing damageable materials and raising utilities is an average cost that was used over a range of structure sizes. Costs for flood vents and installation of the vents were obtained from the flood vent manufacturer. Table 11 provides the breakdown of the wet flood proofing costs.

5. The following changes are required to update the economic analysis and average annual cost information using the current interest rate of 4.0 percent. (An interest rate of 4.125 percent was used in the July 2011 FEIS.):

A. Section 8.0, page 390, second paragraph, last sentence is changed to read: "The selected plan has an overall benefit-cost ratio of 1.80 and would provide in excess of 1-percent chance level of risk reduction for the Fargo-Moorhead Metro Area."

B. Section 3.13.6, page 129, Table 23: Replace Table 23 with the following updated table:

Table 23 - Economic Analysis of the LPP

Account	Item	Flood Risk Management	Recreation	Total
Estimate of Project First Costs LPP				
01	Lands & Damages	278,372		278,372
02	Relocations	154,291		154,291
06	Fish and Wildlife Facilities	61,987		61,987
08	Roads, Railroads and Bridges	60,045		60,045
09	Channels & Canals	783,778		783,778
11	Levees and Floodwalls	143,435		143,435
14	Recreation Facilities		29,800	29,800
Subtotal		$ 1,481,908	$ 29,800	$ 1,511,708
30	Planning, Engineering and Design	179,408	4,442	183,850
31	Construction Management	83,717	2,073	85,790
Subtotal		$ 263,125	$ 6,515	$ 269,640
	Subtotal First Costs	$ 1,745,033	$ 36,315	$ 1,781,348
	Interest During Construction	287,111	726	287,837
	Total Investment Costs	**$ 2,032,144**	**$ 37,041**	**$ 2,069,185**
Estimate of Annual Costs				
	Annualized Project Costs	94,597	1,724	96,321
	Annual OMRR&R Cost	3,501	130	3,631
	Annual Induced Damages	-		-
	Total Annual Costs	**$ 98,098**	**$ 1,854**	**$ 99,952**
Average Annual Benefits				
	Flood Risk Management	162,600	0	162,600
	Flood Proofing Cost Savings	10,430	0	10,430
	Flood Insurance Administrative Costs	960	0	960
	Non Structural Flood Risk Benefit	627		627
	Recreation	-	5,130	5,130
	Total Annual Benefits	**$ 174,617**	**$ 5,130**	**$ 179,747**
	Net Annual Benefits	$ 76,519	$ 3,276	$ 79,795
	Benefit to Cost Ratio	1.78	2.77	1.80

All costs and benefits in thousands ($1,000)
Costs presented at October 2011 price level
Discount Rate = 4.0%
Assumes a 50 year period of analysis

Cover Sheet
FINAL FEASIBILITY REPORT AND ENVIRONMENTAL IMPACT STATEMENT

FARGO-MOORHEAD METROPOLITAN AREA FLOOD RISK MANAGEMENT

LEAD AGENCY: U.S. Army Corps of Engineers, Mississippi Valley Division, St. Paul District (CEMVP)

ABSTRACT: This Final Feasibility Report and Environmental Impact Statement (FEIS) documents the analysis of alternatives developed to reduce flood risk in the entire Fargo-Moorhead Metropolitan area. The Selected Plan is the Locally Preferred Plan (LPP) and includes a North Dakota diversion channel (20,000 cfs), upstream storage and staging, associated structures, non-structural features, recreation features and environmental mitigation.

Privacy Notice: Persons submitting comments are advised that all comments received will be available to the public, to include the possibility of posting on a publicly accessible website. Commenters are requested not to include personal privacy information, such as home addresses, or home phone numbers, in their comments unless they do not object to such information being made available to the public

Comments: Please direct inquiries on this Final Feasibility Report and Environmental Impact Statement (FEIS) to the U.S. Army Corps of Engineers, St. Paul District, Attention: Aaron M. Snyder, 180 E. 5th Street, Suite 700, St. Paul, MN 55101-1678. Telephone (651) 290-5489; Fax (651) 290-5258. **The official closing date for receipt of comments will be 30 days from the date on which the Notice of Availability of the FEIS appears in the <u>Federal Register</u> (scheduled for October 7, 2011).**

Items designated with a * are sections related to the Environmental Impact Statement

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Final Feasibility Report and Environmental Impact Statement Fargo-Moorhead Metropolitan Area Flood Risk Management

EXECUTIVE SUMMARY

STUDY AUTHORITY AND HISTORY

The St. Paul District, Corps of Engineers, and the sponsor cities of Fargo, North Dakota and Moorhead, Minnesota began the Fargo-Moorhead Metro Feasibility Study in September 2008. The study was authorized by a September 30, 1974, Resolution of the Senate Committee to Public Works. Prior to 2008, the Corps conducted numerous studies and projects in the study area. The Fargo-Moorhead metropolitan area was included in the Red River Reconnaissance Study approved in 2002; that study was not to a sufficient level of detail to recommend a feasibility study specifically for measures in Fargo and Moorhead. A supplemental reconnaissance report recommended this feasibility study and was approved by the Mississippi Valley Division on April 8, 2008.

Based on the reconnaissance study findings, the city of Fargo, the city of Moorhead and the federal government entered into a Feasibility Cost Share Agreement on September 22, 2008. The study cost share was 50/50 between the federal government and the two non-federal sponsors. The Corps of Engineers issued a notice of intent to prepare an environmental impact statement in the Federal Register on May 5, 2009. The Draft Feasibility Report and Environmental Impact Statement (DEIS) was published in the Federal Register for a 45 day public review period on June 11, 2010. The review period closed on August 9, 2010 after being extended by 14 days. In response to comments and to more fully study upstream and downstream impacts, the Corps made the decision to prepare a Supplemental DEIS. The notice of intent to prepare a Supplemental DEIS was published in the Federal Register on December 27, 2010.

PURPOSE AND SCOPE

The purpose of the feasibility study was to investigate flood issues in the Fargo-Moorhead Metropolitan Area, identify flood risk management measures that could be implemented, document findings and, if appropriate, recommend implementation of a federal project. The planning objectives were specified as follows:

- Reduce flood risk and flood damages in the Fargo-Moorhead metropolitan area.
- Restore or improve degraded riverine and riparian habitat in and along the Red River of the North, Wild Rice River (North Dakota), Sheyenne River (North Dakota), and Buffalo River (Minnesota) in conjunction with other flood risk management features.
- Provide additional wetland habitat in conjunction with other flood risk management features.
- Provide recreational opportunities in conjunction with other flood risk management features.

The study product is a decision document in the form of an integrated feasibility report and National Environmental Policy Act (NEPA) document in accordance with the Corps' Planning Guidance Notebook, Engineer Regulation (ER) 1105-2-100. The feasibility study investigated measures to reduce flood risk and analyzed the potential for federal participation in implementing a flood risk management project in the Fargo-Moorhead Metropolitan Area. This report allows for tiering supplemental NEPA documentation as permitted by Council on Environmental Quality (CEQ) Regulation 40 C.F.R. 1508.28.

The feasibility study team collected pertinent engineering, economic, social and environmental information needed to accomplish the study objectives. Interagency and public stakeholders and potentially affected landowners were identified. Potential issues and opportunities were defined. An array of possible flood risk management plans was considered and screened to define the costs, benefits, and impacts to the study area.

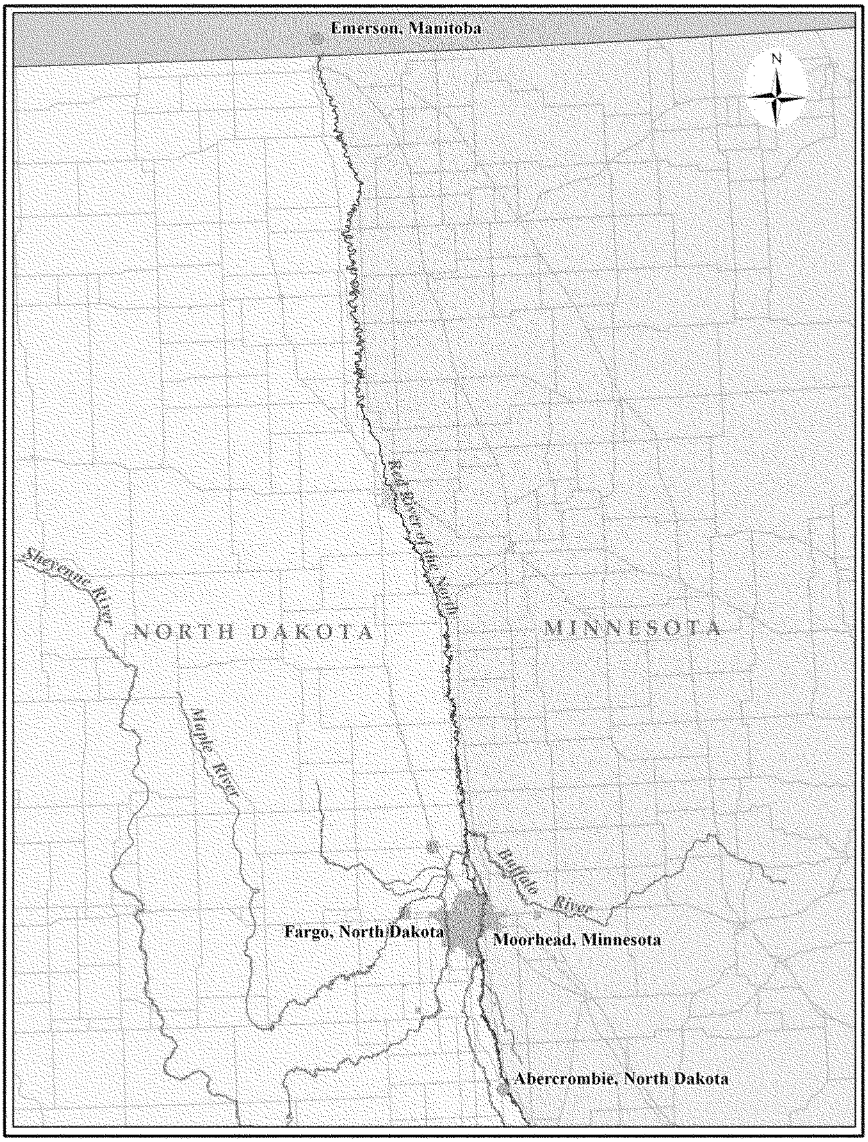
LOCATION OF STUDY AREA

The geographic scope of analysis for the environmental impacts of the proposed action and alternatives encompasses the Fargo-Moorhead Metropolitan area plus areas in the floodplain of the Red River from approximately 300 river miles north of Fargo near Emerson, Manitoba to approximately 30 miles south of Fargo near Abercrombie, ND. The Wild Rice, Sheyenne, Maple, Rush and Lower Rush Rivers in North Dakota and the Buffalo River in Minnesota also cross the study area.

The Fargo-Moorhead metropolitan area is located within the area from approximately 12 miles west to 5 miles east of the Red River and from 20 miles north to 20 miles south of Interstate Highway 94. The metropolitan area is approximately 600 square miles, encompassing several smaller communities within ten miles of the Red River from Hickson, North Dakota to Georgetown, Minnesota. The metropolitan area has a population of approximately 200,000. Fargo-Moorhead is a gateway to the west and a hub of educational and health-related industries. The metropolitan area is the largest urban area in North Dakota and a principal regional economic and social center.

Figure 1 shows the location of the study area.

Figure 1 - Fargo-Moorhead study area location



FLOOD HISTORY

Because of its relatively low elevation and flat topography, the majority of the study area is located in the regulatory floodplain. The Red River of the North has exceeded the National Weather Service flood stage of 18 feet in 48 of the past 109 years, and every year from 1993 through 2011. Flooding in Fargo-Moorhead typically occurs in late March and early April. The flood of record at Fargo-Moorhead was the 2009 spring flood with a stage of 40.8 feet on the Fargo gage. With an estimated peak flow of 29,200 cubic feet per second (cfs), the 2009 flood was approximately a 2-percent chance (50-year) event. Equivalent expected annual flood damages in the Fargo-Moorhead metropolitan area are estimated to be over $194.8 million in the future without project condition. Although emergency measures have been very successful, they may also contribute to an unwarranted sense of security that does not reflect the true flood risk in the area.

ALTERNATIVES CONSIDERED

The study analyzed a number of possible types of measures and alternative plans that could reduce the flood risk in the Fargo-Moorhead metropolitan area. These measures and plans included:

- No Action - Continue emergency measures
- Non-structural measures
- Flood barriers (including levees)
- Increase conveyance (including diversion channels)
- Flood storage

The alternatives went through an initial screening that used the following criteria: Effectiveness, Environmental Effects, Social Effects, Acceptability, Implementability, Cost, Risk, Separable Mitigation, and Cost Effectiveness. The initial screening analysis was published in the Alternatives Screening Document dated December 2009. The analysis resulted in two diversion concepts being carried forward: a diversion in Minnesota and a diversion in North Dakota.

Diversion channel alternatives following alignments primarily in either Minnesota or North Dakota were considered. Channels ranging in capacity from 20,000 to 45,000 cubic feet per second (cfs) were analyzed in detail. The alternatives were named for their location and capacity, for example, the 20,000 cfs channel located in Minnesota was named the "MN20K plan."

STUDY CONCLUSIONS

May 2010 Draft Feasibility Report and Environmental Impact Statement (DEIS)

For the DEIS, the designs, alignments, and features of several diversion channel alternatives were refined, and cost estimates for each alternative were completed. The expected future without project conditions were assessed and compared to the expected future conditions with each alternative in place. The hydraulic and associated economic effects of each alternative were quantified so that the alternatives could be compared. The various alternatives were compared on their ability to meet the goals of the non-federal sponsors as well as cost-effectiveness and environmental impacts.

Table 1 summarizes the results of the economic cost-effectiveness analysis.

Table 1 - Phase 3 cost-effectiveness analysis results

Screened Alternatives Ranked by Net Benefits with Cost and Schedule Risk Assessment

Alternative	Cost [1]	Avg Annual Net Benefits [1]	Avg Annual Benefits [1]	Residual Damages [1]	B/C Ratio
MN Short Diversion 20K	$1,032	$87.0	$140.0	$55.9	2.64
MN Short Diversion 25K	$1,121	$98.8	$156.4	$39.5	2.71
MN Short Diversion 30K	$1,194	$101.7	$163.1	$32.8	2.66
MN Short Diversion 35K	$1,286	$104.9	$171.0	$24.9	2.59
MN Short Diversion 40K [2]	$1,367	$105.6	$175.9	$20.0	2.50
MN Short Diversion 45K [2]	$1,450	$104.9	$179.5	$16.4	2.41
ND East Diversion 35K	$1,462	$95.4	$171.1	$24.8	2.26

1. In millions of dollars with interest during construction and discounting included
2. Estimate based on linear extrapolation
Expected average annual damages without a project were $195.9 million.

Table 2 summarizes the estimated flood stages at the Fargo gage that would be delivered by each of the alternatives if they were operated during a 1-percent chance event or a 0.2-percent chance event.

Table 2 - Phase 3 estimated flood stages assuming various diversion capacities.

	Stage at Fargo Gage (ft)	
	1% Chance (100- year)	0.2% Chance (500- year)
Existing Condition Stage (ft)	42.4	46.7
Existing Condition Flow (cfs)	34,700	61,700
Work Group Goal	30	36
MN20K Diversion Channel	36.9	43.7
MN25K Diversion Channel	34.8	42.4
MN30K Diversion Channel	33.6	41.9
ND35K Diversion Channel	30.6	40.0
MN35K Diversion Channel	31.9	39.6
MN40K Diversion Channel	31.9	37.6
MN45K Diversion Channel	31.9	35.3

Prior to release of the May 2010 DEIS, the study identified three plans of significance to decision makers:

- The National Economic Development plan (NED)
- The Locally Preferred Plan (LPP)
- The Federally Comparable Plan (FCP)

The NED plan was the MN40K diversion. The NED plan provides the greatest net national economic benefit consistent with protecting the Nation's environment.

The LPP was the ND35K diversion. The LPP is the plan that, in the opinion of the non-federal sponsors, best meets the needs of the local community. The cities of Fargo and Moorhead, Cass County, North Dakota and Clay County Minnesota jointly requested that the ND35K plan be pursued as the LPP on March 29, 2010. The request to designate the LPP as the tentatively selected plan was approved by the Assistant Secretary of the Army for Civil Works on April 28, 2010.

The FCP was the MN35K diversion. Normally the NED plan establishes the basis for federal cost sharing of a locally preferred plan, but in this case the LPP provided fewer total annual economic benefits than the NED plan. Therefore, the FCP was used as the basis for federal cost sharing instead of the NED plan. The FCP is a plan that provides comparable total annual economic benefits to the LPP.

The May 2010 DEIS was released for public review on June 11, 2010. In September 2010 hydraulic modeling indicated that the ND35K plan would have more extensive downstream impacts than previously anticipated. Because of that, the decision was made to conduct additional analyses to identify ways to minimize downstream impacts from the LPP.

<u>April 2011 Supplemental Draft Feasibility Report and Environmental Impact Statement (SDEIS)</u>

Beginning in September 2010, several concepts to minimize downstream impacts of a North Dakota diversion plan were considered and studied. The final LPP and tentatively recommended plan was a revised version of the North Dakota diversion channel following the same basic alignment as the ND35K plan, but including additional features to minimize downstream impacts. The primary changes included reducing the diversion channel capacity, raising upstream tie-back levee elevations, adding a 50,000 acre-foot storage area and a 150,000 acre-foot staging area, and compensating most affected landowners within the storage and staging areas. The revised LPP minimized downstream impacts, caused upstream impacts, and provided the same level of risk reduction to the Fargo-Moorhead Metropolitan area as the original LPP (ND35K).

The NED plan was the MN40K plan, and the FCP was the MN35K plan, as discussed above.

<u>July 2011 Final Feasibility Report and Environmental Impact Statement (FEIS)</u>

Following the public comment period on the SDEIS, the Corps considered all of the comments received from agencies, individuals, and other entities. Revisions were made to the SDEIS to incorporate additional analyses and data, and to address the comments received. The NED plan, FCP, ND35K plan, and LPP remain the same as described in the SDEIS.

DESCRIPTION OF THE ND35K PLAN

The ND35K diversion alignment would start approximately four miles south of the confluence of the Red and Wild Rice Rivers and extend west and north around the cities of Horace, Fargo, West Fargo and Harwood. It ultimately would re-enter the Red River north of the confluence of the Red and Sheyenne Rivers near the city of Georgetown, MN. Along the 36 mile path it would cross the Wild Rice, Sheyenne, Maple, Lower Rush and Rush rivers and incorporate the existing Horace to West Fargo Sheyenne River diversion channel.

The basic North Dakota alignment is the same for the ND35K plan and the LPP; the alignment remained the same as in the earlier screening phase, except where it was adjusted northwest of Harwood, ND to avoid Drain 13.

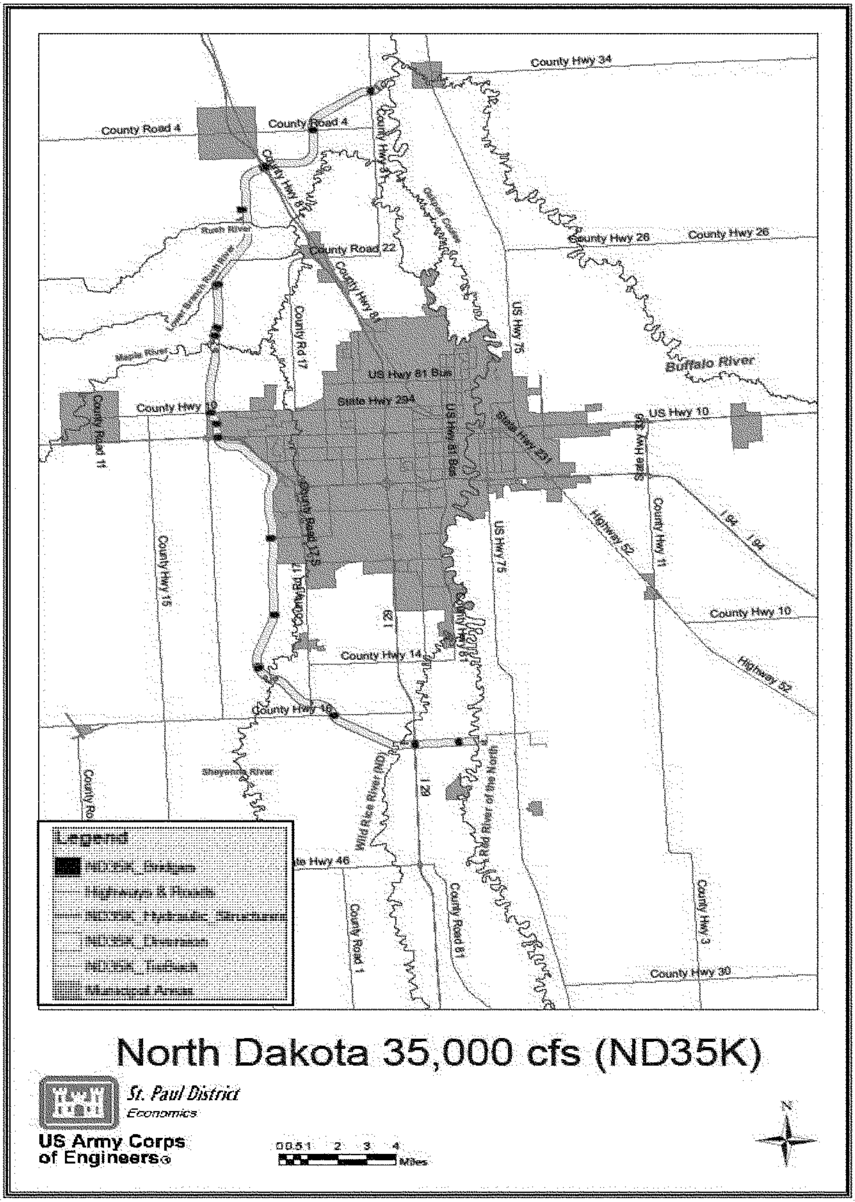
Two hydraulic structures would control the flows passing into the protected area during larger flood events; one on the Red River and the other on the Wild Rice River, with effective flow widths of 120 feet and 60 feet respectively. Both structures would become operable when the forecasted peak flow of the incoming hydrograph in the Red River of the North at the USGS gage in Fargo is greater than 9,600 cfs.

At the Sheyenne and Maple rivers, aqueduct structures would allow base flows to follow the natural river channels to maintain habitat in the natural channels. Flows in excess of a 50-percent chance event would be diverted into the diversion channel. The Lower Rush and Rush rivers would have drop structures that would drop the entire flow of those rivers into the diversion channel. The ND35K diversion channel would also have a tie-back levee that connects the Red River control structure to high ground approximately 2.5 miles to the east and prevents flood water from flowing over land to the north and east into the protected area.

The channel bottom width varies on the channel from 100 to 300 feet and has a maximum depth of 29 feet. The plan includes 18 highway bridges and 4 railroad bridges. The affected acreage is approximately 6,560 acres.

The ND35K plan provides the locally desired level of benefits and follows the locally preferred alignment in North Dakota. The ND35K plan would cause stage increases downstream. Figure 2 shows the alignment of the ND35K plan.

Figure 2 - ND35K Diversion Alignment.



DESCRIPTION OF THE MN35K PLAN (FEDERALLY COMPARABLE PLAN)

The MN35K diversion channel, the FCP, starts just north of the confluence of the Red River and Wild Rice Rivers and extends a total of 25 miles east and north around the cities of Moorhead and Dilworth, ultimately re-entering the Red River near the confluence of the Red and Sheyenne Rivers.

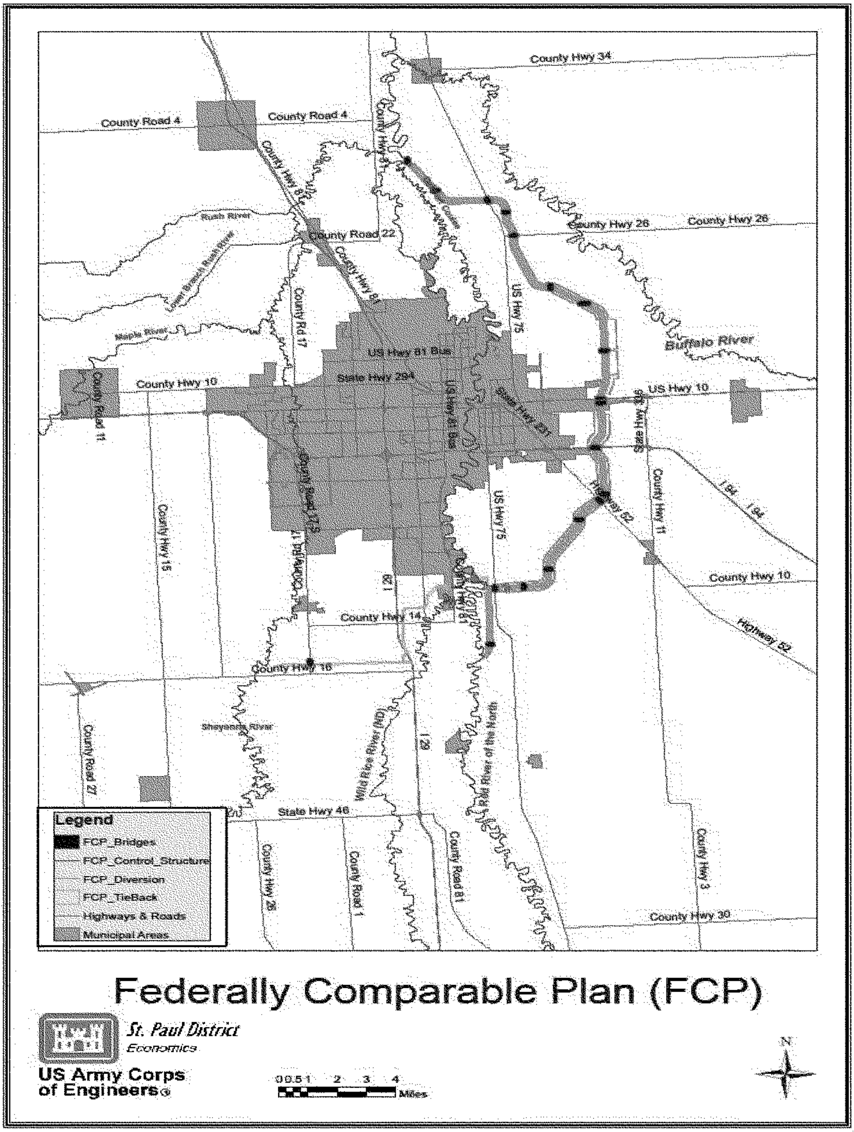
The plan includes a large control structure on the Red River which is an operable structure with three tainter gates. The gates would normally be fully open, and the structure would not impede flow up to a 9,600 cfs flow event when the structure would be put into operation.

The diversion channel has a maximum excavation depth of 30 feet with a maximum bottom width of 400 feet. The total footprint of the diversion channel and soil disposal piles has a maximum width of 2,800 feet, and will affect 6,415 acres of land.

In addition to the diversion channel, the plan includes two smaller channels upstream of the Red River control structure to prevent stage increases upstream of the project along the Red and Wild Rice Rivers. The plan also includes a 9.9 mile tie-back levee at the southern limits of the project. The tie-back levee connects the Red River control structure to high ground and prevents flood water from flowing overland to the north and west into the protected area.

Figure 3 shows the alignment of the FCP.

Figure 3 – Federally Comparable Plan (FCP) Diversion Alignment.



DESCRIPTION OF THE SELECTED PLAN AND LOCALLY PREFERRED PLAN (LPP)

The revised LPP diversion channel is the North Dakota East 20,000 cfs diversion channel with upstream staging and storage. This is the selected plan and the locally preferred plan (LPP).

The LPP diversion alignment would start approximately four miles south of the confluence of the Red and Wild Rice Rivers and extend west and north around the cities of Horace, Fargo, West Fargo and Harwood. It ultimately would re-enter the Red River north of the confluence of the Red and Sheyenne Rivers near the city of Georgetown, MN. Along the 36 mile path it would cross the Wild Rice, Sheyenne, Maple, Lower Rush and Rush rivers and incorporate the existing Horace to West Fargo Sheyenne River diversion channel.

The basic North Dakota alignment is the same for the ND35K plan and the LPP; the alignment remained the same as in the earlier screening phase, except where it was adjusted northwest of Harwood, ND to avoid Drain 13. Some significant design changes were made for the LPP including the addition of staging and storage, along with optimization of the channel cross section. The plan includes 19 highway bridges and 4 railroad bridges that cross the diversion channel.

The LPP channel capacity was modified from previous phases to account for the storage and staging areas that were included. The inclusion of these areas allowed for the capacity of the diversion channel to be reduced to approximately 20,000 cfs. The diversion channel was designed to keep the 1-percent chance event flood flows below existing ground in the diversion channel as much as possible to limit impacts to drainage outside the channel.

Two hydraulic structures would control the flows passing into the protected area during larger flood events; one on the Red River and the other on the Wild Rice River, with effective flow widths of 150 feet and 60 feet, respectively. Both structures would become operable when the forecasted peak flow of the incoming hydrograph in the Red River of the North at the USGS gage in Fargo is greater than 9,600 cfs.

The diversion inlet structure is located where the diversion channel crosses Cass County Highway 17 south of Horace, ND. The outlet structure located where the diversion returns to the Red River of the North would be a concrete spillway.

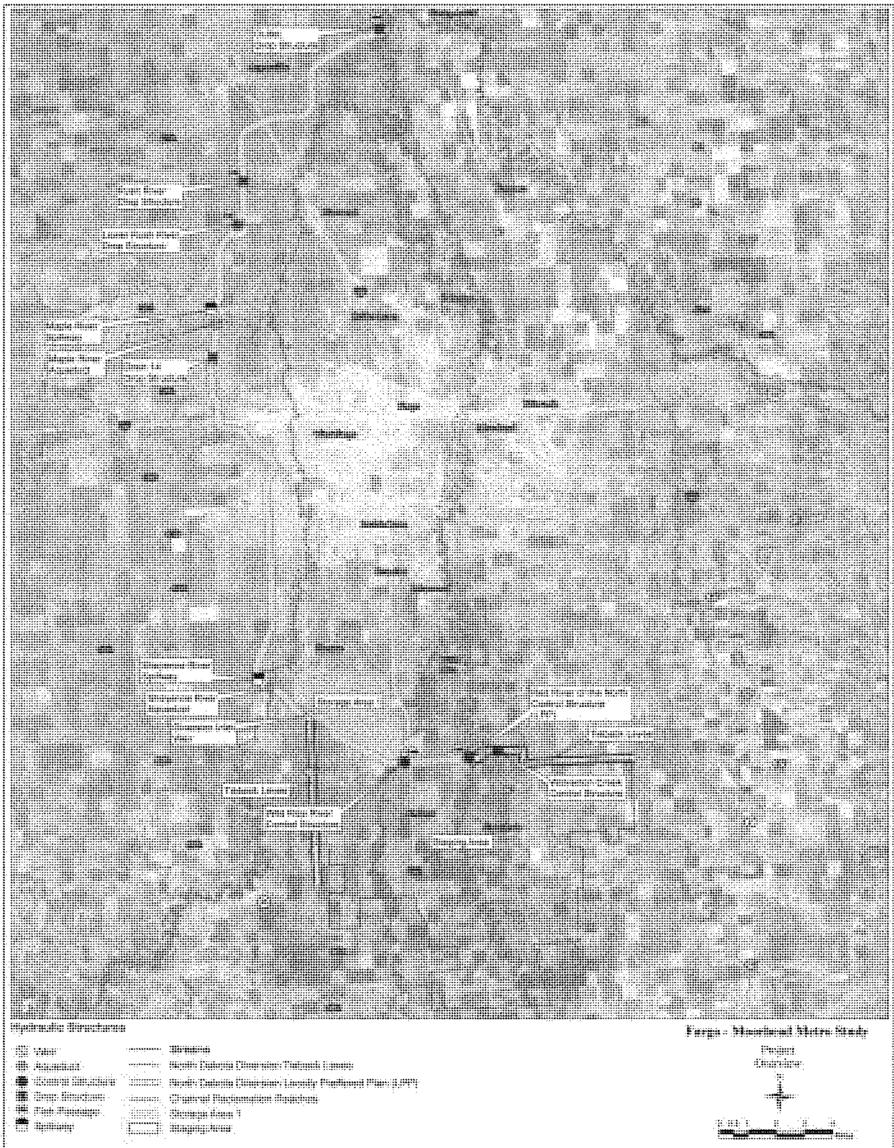
At the Sheyenne and Maple rivers, aqueduct structures would allow base flows to follow the natural river channel. Flows in excess of a 50-percent chance event would be diverted into the diversion channel. The Lower Rush and Rush rivers would have drop structures that would drop the entire flow of those rivers into the diversion channel.

The depth of the diversion channel is approximately 20 feet, with a maximum depth of 35 feet. The channel bottom width varies on the channel from 100 to 250 feet. The total footprint of the LPP diversion channel has a maximum width of 2,200 feet including areas for soil disposal piles. The affected acreage is 8,054 acres.

The main line of flood protection at the south end of the project includes the embankments adjacent to the diversion channel, Storage Area 1 embankments, and a tie-back levee from the Red River control structure to high ground in Minnesota.

In order to eliminate downstream impacts, upstream staging and storage of approximately 200,000 acre-feet immediately upstream of the diversion channel inlet would be required. Figure 4 shows the area that would be affected by staging. Storage Area 1 is a 4,360-acre area on the north side of the LPP diversion channel between the Wild Rice River and the Sheyenne River that will be formed by nearly 12 miles of embankments and will provide 50,000 ac-ft. of storage. Storage Area 1, combined with staging in the floodplain, will nearly eliminate impacts from the project on flood levels downstream of the diversion channel outlet. A tie-back levee along Cass County Road 17 (CR17) would be included to keep staged water from crossing overland into the Sheyenne River. Figure 4 shows the alignment and major features of the LPP.

Figure 4 – LPP Diversion Alignment and Features



The total estimated first cost (without interest during construction) of the LPP based on October 2011 price levels is $1,781,348,000, with the federal and non-federal shares of total first cost estimated at $801,542,000 and $979,806,000, respectively. The flood risk management features have an estimated total first cost of $1,745,033,000, with the federal and non-federal shares estimated at $783,384,000 and $961,649,000, respectively. The recreation features have an estimated total first cost of $36,315,000, with the federal and non-federal shares estimated at $18,157,500 and $18,157,500 respectively. The annual operation and maintenance costs are $3,631,000. The selected plan has an overall benefit-cost ratio of 1.76 and would provide in excess of 1-percent chance level of risk reduction for the Fargo-Moorhead Metro Area. Table 3 shows the breakout of the project first costs, interest during construction, and the project benefit cost ratio. Table 4 shows the breakout of project costs split between the non-federal sponsors and the federal government, along with the estimated cash contribution that is required.

Table 3 - Estimated Project Costs for the LPP (including interest during construction)

Account	Item	Flood Risk Management	Recreation	Total
Estimate of Project First Costs LPP				
01	Lands & Damages	278,372		278,372
02	Relocations	154,291		154,291
06	Fish and Wildlife Facilities	61,987		61,987
08	Roads, Railroads and Bridges	60,045		60,045
09	Channels & Canals	783,778		783,778
11	Levees and Floodwalls	143,435		143,435
14	Recreation Facilities		29,800	29,800
Subtotal		$ 1,481,908	$ 29,800	$ 1,511,708
30	Planning, Engineering and Design	179,408	4,442	183,850
31	Construction Management	83,717	2,073	85,790
Subtotal		$ 263,125	$ 6,515	$ 269,640
	Interest During Construction	296,914	791	297,705
	Total Investment Costs	**$ 2,041,947**	**$ 37,106**	**$2,079,053**
Estimate of Annual Costs				
	Annualized Project Costs	97,097	1,764	98,861
	Annual OMRR&R Cost	3,501	130	3,631
	Annual Induced Damages	-		-
	Total Annual Costs	**$ 100,598**	**$ 1,894**	**$ 102,492**
Average Annual Benefits				
	Flood Risk Management	162,800	0	162,800
	Flood Proofing Cost Savings	10,430	0	10,430
	Flood Insurance Administrative Costs	960	0	960
	Non Structural Flood Risk Benefit	627		627
	Recreation	-	5,130	5,130
	Total Annual Benefits	**$ 174,817**	**$ 5,130**	**$ 179,947**
	Net Annual Benefits	$ 74,219	$ 3,236	$ 77,455
	Benefit to Cost Ratio	1.74	2.71	1.76

All costs and benefits in thousands ($1,000)

Table 4 – Allocation of funds table (first costs).

LPP			
Item	Federal ($)	Non-Federal ($)	Total ($)
Flood Risk Management			
Lands and Damages		278,372	278,372
Relocations	60,045	154,291	214,336
Fish and Wildlife Facilities	61,987		61,987
Channels and Canals	783,778	0	783,778
Levees and Floodwalls	143,435	0	143,435
Planning, Engineering, & Design	156,408	23,000	179,408
Construction Management	72,985	10,732	83,717
Cash Contribution	-495,253	495,253	0
Total FRM	783,384	961,649	1,745,033
Recreation			
Lands and Damages	0	0	0
Relocations	0	0	0
Recreation Facilities	29,800	0	29,800
Planning, Engineering, & Design	4,442	0	4,442
Construction Management	2,073	0	2,073
Cash Contribution	-18,158	18,158	0
Total Recreation	18,158	18,158	36,315
Total Project	801,542	979,806	1,781,348
All costs in thousands ($1,000)			

EFFECTS OF THE PROJECT

Implementing any of the diversion channel alternatives would result in a substantial beneficial effect on the local economy by significantly reducing flood damages and flood risk, improving public safety and peace of mind. All of the plans would remove much of the Fargo-Moorhead area from the regulatory floodplain. The LPP and ND35K would benefit a larger geographic area and more people than the FCP would. All of the diversion channel alternatives would significantly reduce flood damage and flood risk, but neither of the plans would completely eliminate the flood risk.

The diversion channel alternatives would change the flow and timing of water during flood events, significantly reducing the quantity of water flowing through the communities of Fargo-Moorhead. As a result, all alternatives will increase flood elevations and alter the timing of flooding for areas downstream and/or upstream of the Fargo-Moorhead Metropolitan Area. For the LPP, downstream impacts are nearly eliminated with the addition of upstream staging and storage. Upstream staging under the LPP diversion alternative will not substantially change flow velocities near the Red River channel banks during conditions when water is staged.

There are 4,626 acres of wetlands in the project area, which is less than 0.05% of the area within the project boundary. The FCP could impact approximately 976 acres of wetlands. The LPP and ND35K could impact approximately 1153 acres and 1053 acres, respectively. Any alternative would include appropriate measures to avoid, minimize, and compensate for potential losses of wetland areas.

Groundwater resources in the project area include the Buffalo Aquifer and the West Fargo Aquifer. The Buffalo Aquifer, located five to seven miles east of Moorhead and a mile east of the Minnesota alignment, is not expected to experience measureable effects from the diversion channel. The West Fargo Aquifer appears to be deep enough to avoid adverse impacts from the North Dakota alignment. The three diversion channel alternatives are not expected to have adverse impacts to significant groundwater resources in the study area.

All of the diversion channel alternatives could alter hydraulic conditions for the Red River. The ND35K and LPP would also affect five tributaries and Wolverton Creek. However, none of the diversion channel alternatives would substantially alter sediment transport or other key geomorphic properties. Ultimately, it is not anticipated that any of the alternatives would substantially contribute to any adverse geomorphic conditions either downstream or upstream of the study area. And while channel slope could be increased for short areas adjacent to several project structures, careful project design should minimize any potential for destabilization of the stream bed or stream banks.

Connectivity and habitat for fisheries is a concern throughout the river basin and for all three diversion channel alternatives. Habitat connectivity is important in terms of fulfilling seasonal and life stage-specific habitat needs for river fish. The LPP could have a potentially significant impact to aquatic habitat connectivity on the Red and Wild Rice rivers. As such, the LPP includes several minimization and mitigation measures to reduce the level of this impact. The FCP and ND35K could slightly reduce the level of biological connectivity relative to existing conditions; however, any effects would be small. The FCP and ND35K include measures to minimize impacts to connectivity to levels that would be less than significant in terms of impacts to long-term Red River fish populations and community trends. The FCP will have the least impact to connectivity, as impacts are limited to the Red River mainstem. The ND35K would be slightly worse as connectivity could affect the Red and Wild Rice rivers. However, under these two alternatives, efforts were made to minimize impacts to connectivity. Any reductions to biological connectivity would be small and not anticipated to noticeably affect fish populations or communities of the Red River or associated tributaries. Ultimately, the LPP, FCP and ND35K could slightly reduce levels of biological connectivity to varying degrees. However, with proposed minimization and mitigation measures for each alternative, these reductions would be negated, and not significantly affect fish populations or communities, relative to existing conditions. The risk to fish stranding in the floodplain for the LPP will require additional consideration during development of the project operating plan, to include observation during the first few flood events to determine resulting stranding.

The FCP, LPP and ND35K would remove approximately 5,889, 6,878 and 6,540 acres of prime and unique farmland from operation, respectively. The plans would result in acquisition of farmland in Clay County, MN or Cass County, ND. All three diversion channel alternatives would result in a great deal of prime and unique farmland being impacted but the impact is considered to be less than significant based on the large quantity of farmland in the study area and the fact that over 90-percent of all farmland is considered prime and unique in this region.

Both the Minnesota and North Dakota alignments would require dwelling relocation and cause direct impacts to affected landowners. The LPP will require a substantial number of relocations for communities in the staging area. Owners would be justly compensated for their property and relocation, but communities in the staging area would be adversely impacted.

Recreational features are included in all three diversion channel alternatives. Recreation features would include, but not be limited to, multipurpose trails, interpretive signage, benches, and trail heads with parking facilities. The recreation plan could result in a healthier, more vibrant community. The plantings associated with the recreation would aesthetically improve the area and enhance the overall experience. Recreational features could also add social and economic benefits to the metropolitan region.

RECOMMENDATIONS

The St. Paul District Engineer, after considering the environmental, social, and economic effects, the engineering feasibility, and comments received from the other resource agencies, the non-federal sponsors, and the public, has determined that the selected plan presented in this report is in the overall public interest and is technically sound, environmentally acceptable, and economically feasible. The St. Paul District Engineer recommends that the Locally Preferred Plan, the North Dakota East 20,000 cfs diversion channel with upstream staging and storage, and associated features described in this report, be authorized for implementation as a federal project. This plan is being recommended with such modifications thereof as in the discretion of the Commander, HQUSACE, may be advisable.

1.0 STUDY INFORMATION

1.1 STUDY AUTHORITY

The Fargo-Moorhead Metropolitan Area is part of the Red River of the North Basin. The Red River Reconnaissance Study was authorized by a September 30, 1974, Resolution of the Senate Committee on Public Works:

> *RESOLVED BY THE COMMITTEE ON PUBLIC WORKS OF THE UNITED STATES SENATE, That the Board of Engineers for Rivers and Harbors be, and is hereby, requested to review reports on the Red River of the North Drainage Basin, Minnesota, South Dakota and North Dakota, submitted in House Document Numbered 185, 81st Congress, 1st Session, and prior reports, with a view to determining if the recommendations contained therein should be modified at this time, with particular reference to flood control, water supply, waste water management and allied purposes.*

The Fargo-Moorhead metropolitan area was included in the Red River Basin Reconnaissance Study approved on September 19, 2002, but the level of detail in that report was insufficient to recommend a feasibility study specifically for measures in Fargo, North Dakota, and Moorhead, Minnesota. A supplemental Reconnaissance Study for Fargo-Moorhead was approved by the Mississippi Valley Division on April 08, 2008.

Based on the recommendations contained in the Reconnaissance Report the city of Fargo, the city of Moorhead and the federal government entered into a Feasibility Cost Share Agreement on September 22, 2008. The study was cost shared 50/50 between the two non-federal sponsors and the federal government. Funds to initiate the feasibility study were provided in the Consolidated Appropriations Act, 2008, approved December 26, 2007 (Public Law 110-161). The Corps of Engineers issued a Notice of Intent to prepare an environmental impact statement (EIS) in the Federal Register on May 5, 2009.

The Federal Water Project Recreation Act of 1965 (Public Law 89-72), as amended, requires an agency to fully consider recreational features that may be associated with Federal flood risk management projects.

1.2 PURPOSE AND SCOPE

The purpose of this feasibility study was to identify measures to reduce flood risk in the entire Fargo-Moorhead Metropolitan Area. This report documents the plan formulation studies conducted by the St. Paul District of the U.S. Army Corps of Engineers in close cooperation with the non-federal sponsors.

The study objectives were as follows:

1) To understand the flood problems in the greater Fargo-Moorhead Metropolitan area and develop a regional system to reduce flood risk.

2) To determine the federal government's role in implementing flood risk management measures in Fargo-Moorhead.
3) To document study findings in a Feasibility Report and Appropriate National Environmental Policy Act (NEPA) document (either an Environmental Assessment or an Environmental Impact Statement).
4) If appropriate, recommend implementation of a federal project to the U.S. Congress.

The study team collected and evaluated pertinent engineering, economic, social, and environmental information needed to accomplish the study objectives. An array of possible flood risk management plans were considered and screened to define the costs, benefits, and impacts to the project area.

The study product is a decision document in the form of an integrated feasibility report and NEPA document in accordance with the Corps' Planning Guidance Notebook, Engineer Regulation (ER) 1105-2-100. The feasibility study investigated measures to reduce flood risk and analyzed the potential for federal participation in implementing a flood risk management project in the Fargo-Moorhead Metropolitan Area. This report will allow for tiering supplemental NEPA documentation as permitted by Council on Environmental Quality (CEQ) Regulation 40 C.F.R. 1508.28.

1.3 LOCATION OF THE STUDY AREA

The study location is shown on Figure 5. The geographic scope of analysis for the environmental impacts of the proposed action and alternatives encompasses the Fargo-Moorhead Metropolitan area plus areas in the floodplain of the Red River from approximately 300 river miles north of Fargo near Emerson, Manitoba to approximately 30 miles south of Fargo near Abercrombie, ND. The Fargo-Moorhead Metropolitan area is located within the area from approximately 12 miles west to 5 miles east of the Red River and from 20 miles north to 20 miles south of Interstate Highway 94. The Fargo-Moorhead area is shown on Figure 6.

The study area is located in the At Large Congressional District of North Dakota (Congressman Rick Berg - R) and Minnesota's Seventh Congressional District (Congressman Collin Peterson – D).

Fargo-Moorhead is located along the banks of the Red River of the North. The Wild Rice, Sheyenne, Maple and Rush Rivers in North Dakota and the Buffalo River in Minnesota also cross the study area. Fargo and Moorhead are on the west and east banks of the Red River of the North, respectively. The Red River of the North flows north approximately 453 river miles to Lake Winnipeg in Manitoba, Canada. The drainage area of the Red River of the North above the U.S. Geological Survey gauging station at Fargo is approximately 6,800 square miles, of which about 2,175 square miles do not contribute to runoff.

Figure 6 shows the Fargo-Moorhead Metro area and the topography on a color-shaded plot. Dark blue represents the lowest elevations and dark brown represents the highest elevations. This plot illustrates that the land, while generally very flat, slopes down from South to North.

Figure 5 - Fargo-Moorhead Location

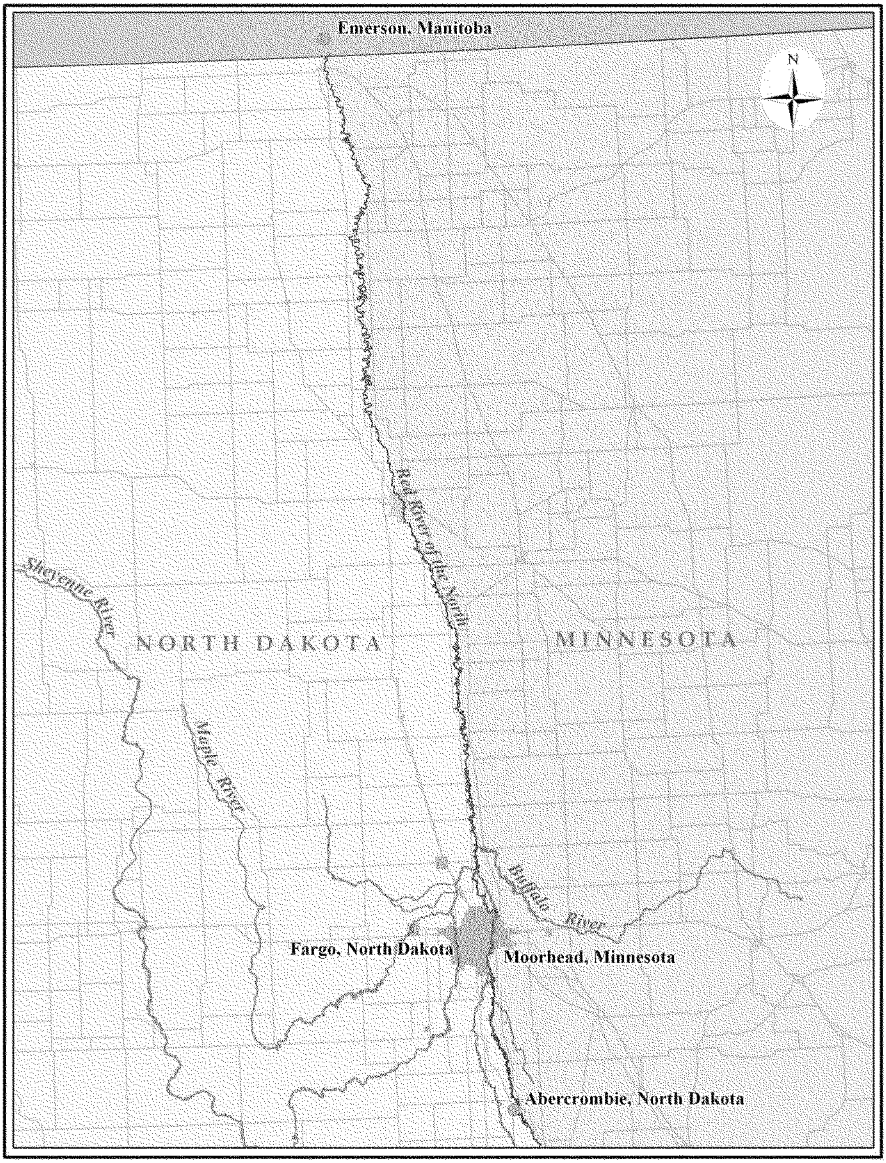
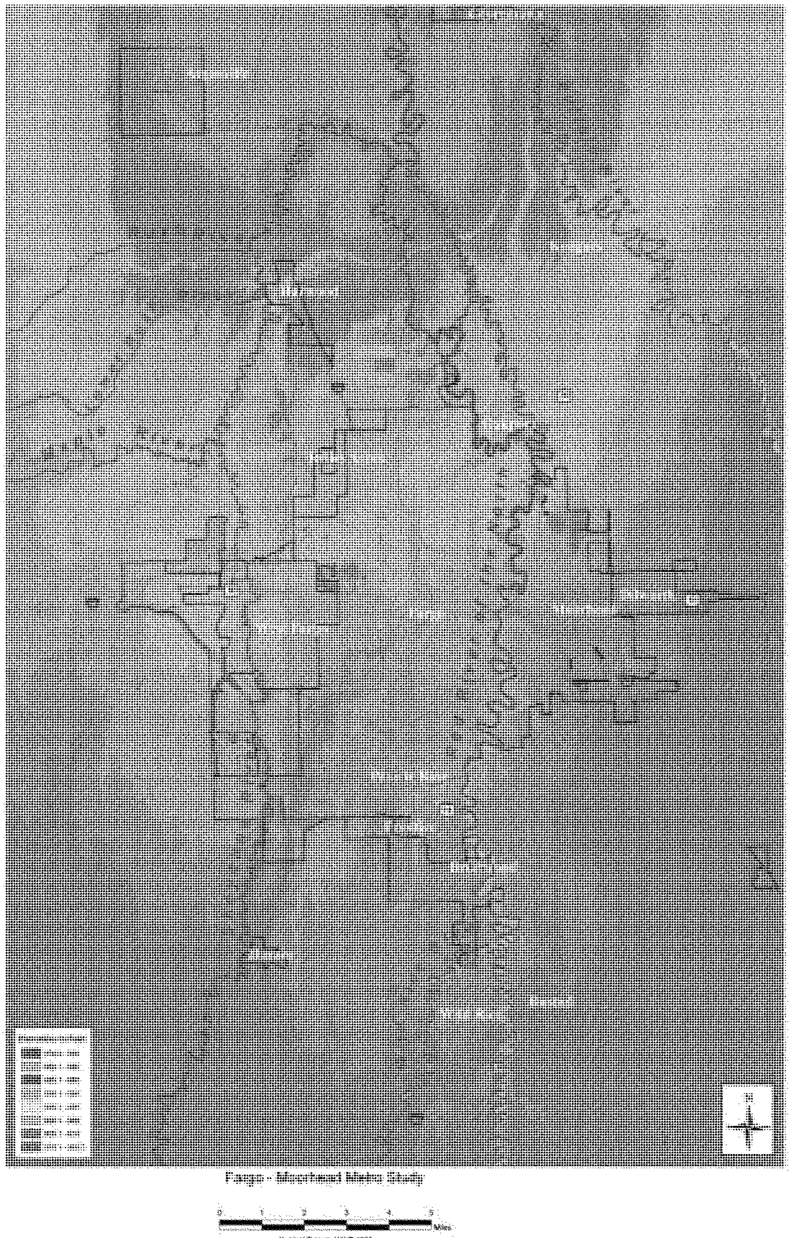


Figure 6 – Metro Area topography



1.4 HISTORY OF THE INVESTIGATION

The Fargo-Moorhead metropolitan area has a relatively high risk of flooding. The highest river stages usually occur as a result of spring snowmelt, but summer rainfall events can also cause significant flood damages. The Red River of the North has exceeded the National Weather Service flood stage of 18 feet in 48 of the past 109 years, and every year from 1993 through 2011. The study area includes the Wild Rice River, the Sheyenne River, and the Red River of the North; interbasin flows complicate the hydrology of the region and contribute to extensive flooding. Current estimates of the average annual flood damages in the Fargo-Moorhead metropolitan area are over $194.8 million.

In June, 2006, the City of Fargo requested that the Corps study a floodwall concept along 2nd Street near City Hall under the Section 205 continuing authority. Discussion with the cities of Fargo and Moorhead led to an expansion of the scope of study to include the entire metropolitan area. Funds to conduct a Reconnaissance study were received in April 2007, and the Reconnaissance study was completed in April 2008. The Corps and the cities of Fargo and Moorhead began the Fargo-Moorhead Metro feasibility study in September 2008. The flood of 2009 heightened awareness of the flood risk in the study area and significantly increased public and political interest in study activities.

Fargo, Moorhead and the other communities in the study area have become accustomed to dealing with flooding. Sufficient time is usually available to prepare for flood fighting, because winter snowfall can be monitored to predict unusual spring runoff. The communities have well documented standard operating procedures for flood fights. Fargo and Moorhead avoided major flood damages in the historic floods of 1997 and 2009 by either raising existing levees or building temporary barriers. After the 1997 flood, both communities implemented mitigation measures including acquisition of nearly 100 floodplain homes, raising and stabilizing existing levees, installing permanent pump stations and improving storm sewer lift stations and the sanitary sewer system. These actions paved the way for a successful flood fight during the record-setting 2009 flood event. The communities have continued to buy flood-prone homes and improve flood-related infrastructure in the wake of the 2009 flood. Although emergency measures have been very successful, they may also contribute to an unwarranted sense of security that does not reflect the true flood risk in the area.

1.5 PRIOR REPORTS AND EXISTING PROJECTS

1.5.1 Reports

Since the 1940s, the Corps of Engineers and others have prepared numerous reports on the Red River of the North basin. The following reports contain the most relevant information for the current effort:

1.5.1.1 House Document 185, 81st Congress, 1st Session, dated May 24, 1948. This report proposed a comprehensive plan for the Red River of the North basin. The plan included channel improvements, levees and floodwalls in Fargo and Moorhead. Other components of the plan included the Orwell Reservoir on the Ottertail River in Minnesota; channel improvements on the lower Sheyenne, Maple and Rush Rivers in North Dakota; channel improvements on the Mustinka, Ottertail, Wild Rice, Marsh and Sand Hill Rivers in Minnesota; channel improvements along the Bois de Sioux and upper Red Rivers near Wahpeton, North Dakota/Breckenridge, Minnesota; and local flood protection works on the Red River in Grand Forks, North Dakota/East Grand Forks, Minnesota. The study found that channel improvements along the lower 31.6 miles of the Wild Rice River in North Dakota were economically justified, but the majority of affected local interests did not support the project, so it was not recommended. The report specifically recommended no further investigations in the Buffalo River basin and several other basins in Minnesota.

1.5.1.2 Section 205, Flood Control Reconnaissance Report, Red River of the North at Fargo, North Dakota, Corps of Engineers, May 1967. This study evaluated the potential to build a portion of the levee in Fargo that had been approved as part of the 1948 comprehensive plan but was later omitted from the constructed project. The study concluded that the proposed project was not economically feasible and did not warrant further Federal involvement at that time.

1.5.1.3 Fargo-Moorhead Urban Study, Corps of Engineers, May 1985. This study was a cooperative Federal, State and local planning effort aimed at developing viable solutions to water and related land resource problems, needs and concerns for 1980 to 2030. The study area encompassed 13 townships in Cass County, North Dakota and Clay County, Minnesota. The study addressed water supply, water conservation, flood risk management, energy conservation and water resources data management. The study evaluated the potential to construct levees, floodwalls and channel modifications in Fargo and Moorhead. The report concluded that extremely long levees or floodwalls would be required to ring the urban areas to provide adequate protection from larger floods and the costs would greatly exceed the damages prevented. Therefore, Federal participation in Fargo and Moorhead flood risk management projects was not recommended. However, the report did support further studies for flood control in Harwood and Rivertree Park, North Dakota.

1.5.1.4 Federal Tier 1/State Generic "Environmental Impact Study of Flood Control Impoundments in Northwestern Minnesota," Corps of Engineers and Minnesota Department of Natural Resources, July 1996. This study was a joint Federal and State effort and it addressed the potential water surface impoundments in the Red River of the North watershed. This joint EIS was challenged in Minnesota district court, and in 1997, the Minnesota Legislature authorized funding for a "Mediation" process to resolve disputed issues and permitting gridlock.

1.5.1.5 "Living with the Red," International Joint Commission, November 2000. In June 1997, following record-setting flooding on the Red River of the North, the governments of Canada and the United States asked the International Joint Commission (IJC) to examine and report on the causes and effects of damaging floods in the Red River basin and to make recommendations on means to reduce, mitigate and prevent harm from future flooding." The IJC established the International Red River Basin Task Force to undertake the necessary studies. The task force produced its report in April 2000. The IJC's report, entitled "Living with the Red," was completed in November 2000. These reports included discussion of the flooding in the Fargo-Moorhead area. The report cited hydraulic and hydrologic analyses conducted after the 1997 flood that indicated flood risks in the Fargo-Moorhead area were likely greater than previously thought. The report supported a basin-wide flood mitigation approach including reduction in flows, strengthening of existing protection structures and use of other techniques. The report recommended that Federal, State and local governments should "expedite the study of flood risk potential and implement plans for flood protection measures for the Fargo-Moorhead area."

1.5.1.6 Reconnaissance Study, Red River Basin, Minnesota, North Dakota, South Dakota, Corps of Engineers, September 2001. This study, supported by supplemental information, was approved in October 2002. The study recommended three initial feasibility studies to be followed by additional studies throughout the basin. Only the initial three studies were approved in 2002. The additional proposed studies would be considered for approval on the basis of additional 905(b) analyses. The Fargo-Moorhead and Upstream feasibility study, currently underway, was one of the initial studies recommended and approved in the reconnaissance study.

1.5.1.7 Final Environmental Impact Statement (FEIS) for the Red River Valley Water Supply Project, U.S. Department of the Interior, Bureau of Reclamation, December 21, 2007. The purpose of the proposed project is to meet the comprehensive water quality and quantity needs of the Red River Valley through the year 2050. The needs were identified as municipal, rural and industrial water; water quality; aquatic environment; recreation; and water conservation measures. The preferred alternative would import water to the Red River basin from the Missouri River via the Garrison Diversion and the Sheyenne River.

1.5.1.8 Fargo-Moorhead Downtown Framework Plan Update, Fargo-Moorhead Council of Governments, City of Fargo, and City of Moorhead, June 2007. This report builds upon earlier planning efforts in both Fargo and Moorhead. Many of the concepts presented depend on implementation of effective flood risk management strategies.

1.5.1.9 Flood Retention: Not Always the Silver Bullet, The North Dakota State Water Commission, North Dakota Water, March 2010, pages 16-18, http://www.swc.state.nd.us/4dlink9/4dcgi/GetContentPDF/PB-1755/OxbowMar10.pdf. This report states that flood retention has many challenges, including the need for a large amount of land, complicated timing of the operation of the storage cells, and the requirement that the storage cells be in the right location for the particular flood source.

1.5.2 Current Studies

The following studies are being conducted:

1.5.2.1 Fargo-Moorhead and Upstream Feasibility Study, Corps of Engineers. The study began in August 2004. The study area is the entire headwaters of the Red River of the North upstream (south) of the Fargo-Moorhead metropolitan area. The major tributaries are the Mustinka, Bois de Sioux and Ottertail Rivers in Minnesota and the Wild Rice River in North Dakota. The study is evaluating alternatives that would restore wetland habitat and reduce flood damages. The major underlying assumption is that a system of surface water storage sites upstream of Fargo-Moorhead would reduce flood stages and flood damages downstream. It is also assumed that water storage could be accomplished in ways that would restore aquatic ecosystems and increase habitat for wildlife. Phase 1 analyses, completed in June 2005, showed that distributed flood storage could provide significant economic benefits, but additional study of environmental benefits is needed to justify a Federal project. The North Dakota State Water Commission and the City of Moorhead are jointly sponsoring the study. Additional cost-share partners include the Southeast Cass Water Resource District; Richland County Water Resource District; Red River Joint Water Resource District; city of Fargo; Buffalo-Red River Watershed District; Bois de Sioux Watershed District; Minnesota Department of Natural Resources; Minnesota Board of Water and Soil Resources; Minnesota Pollution Control Agency; South Dakota Department of Game, Fish, and Parks; and Red River Basin Commission.

1.5.2.2 Fargo Southside Flood Control Project, City of Fargo, North Dakota. After the 1997 flood, the city of Fargo and the Southeast Cass County Water Resource District conducted planning for a flood risk management project to protect developments in the area south of Fargo and north and west of the Wild Rice River up to 4 miles south of its confluence with the Red River. Several alternatives were explored, including combinations of levees, diversion channels, channel modifications and flood storage. The Southside study was discontinued when it was overcome by the Fargo-Moorhead Metro feasibility study (the subject of this report). The Southside study will resume only if no federal project is recommended to address flooding in the area south of Fargo.

1.5.2.3 Oakport Township, Minnesota. The Buffalo-Red River Watershed District is working on a flood risk management project for Oakport Township. The project is designed to protect areas of town to a level equal to the 2009 flood plus 3 feet. The project includes ring levees on either side of Oakport Coulee and buying several homes that cannot be protected by the levee system. A Corps of Engineers study performed under the Section 205 Continuing Authority was terminated in December 2002 after it was determined that national economic benefits were insufficient to support further Federal efforts.

1.5.2.4 Flood Insurance Study Update, Federal Emergency Management Agency (FEMA). FEMA is updating the flood insurance maps for the Fargo-Moorhead area. As a result of recent flood events and revised hydrologic and hydraulic modeling, FEMA is likely to increase the 1-percent-chance flood elevation on the order of 1 foot above the current administratively determined elevation. Two studies have defined the hydraulics and hydrology in the area. The Stanley and Pleasant Townships, Cass County, ND and Holy Cross and Kurtz Townships, Clay County, MN Flood Insurance Study addresses the area south of Fargo, ND. The City of Fargo, North Dakota Flood Insurance Study addresses the Fargo-Moorhead area.

1.5.2.5 Non-federal studies. There are a number of ongoing non-federal studies in the watershed upstream of the study area analyzing the potential for flood storage on the Wild Rice River, Sheyenne River, Maple and Rush rivers.

1.5.3 <u>Existing Water Resource Projects</u>

1.5.3.1 The Lake Traverse project, including White Rock Dam and Reservation Dam, provides flood storage at the headwaters of the Bois de Sioux and Red River of the North. The project was authorized by the 1936 Flood Control Act and construction was completed in 1948. The project is operated by the Corps of Engineers, St. Paul District.

1.5.3.2 Baldhill Dam and Lake Ashtabula provide water storage for flood control and water supply on the Sheyenne River. The project was authorized by the 1944 Flood Control Act and construction was originally completed in 1951. The dam was modified in 2004 to raise the flood control pool by 5 feet. (The pool raise was part of the Sheyenne River project described in section 1.5.3.10 below.)

1.5.3.3 The Orwell Dam provides water storage for flood control and water supply on the Otter Tail River. The dam was included in the Corps' 1947 comprehensive plan for the Red River basin and authorized by the Flood Control Acts of 1948 and 1950. Construction of the dam was completed in 1953; it provides 8,600 acre-feet of flood storage.

1.5.3.4 Fargo levees: The Corps participated in a permanent flood control project completed in Fargo in 1963. The project was recommended in the Corps' 1948 comprehensive plan for the Red River basin and authorized by the Flood Control Acts of 1948 and 1950. The project included four channel cutoffs, the Midtown Dam and a 3,500-foot levee east of Fourth Street South between First Avenue South and Tenth Avenue South. The top of levee is at approximately a 40.0-foot stage. The city later extended the levee south to Thirteenth Avenue. Fargo has several other publicly and privately owned sections of levee and floodwall throughout the city. The current line of protection has top elevations that vary from a stage of 30 feet to 42 feet, but most reaches are at or below 37 feet. (Note: the proposed new FEMA 1-percent-chance flood stage is expected to be approximately 39.3 feet.)

1.5.3.5 Moorhead levees: There are no federally constructed levees in Moorhead. The Corps proposed a 1,800-foot-long levee in the 1948 comprehensive plan for the Red River basin. It was authorized by the Flood Control Acts of 1948 and 1950, but the city declined to participate in the project. The city has built four small levees and several lift stations and control structures on storm water lines that can be closed or operated during high-water events. The city has also installed valves on the sanitary sewer lines at several individual flood-prone residences to prevent floodwater from inundating the system. The city also builds emergency levees when necessary.

1.5.3.6 Rush River Channel Improvement: The Corps participated in the channel improvement project completed in 1956. The improvement was authorized by the Flood Control Acts of 1948 and 1950. The project extends along the Rush River from a point near Amenia, North Dakota to the mouth at the Sheyenne River. The improvements consist of channel clearing, enlargement and straightening. Appurtenant construction in connection with the project includes stone riprap at bridges, a drop structure, stone protection at three culvert outlets and ditching. The project provides flood risk management for the flood plain lying adjacent to the channel improvement by confining all flood levels up to those having an occurrence frequency of about once in 10 years.

1.5.3.7 Lower Rush River Channel Improvement: The improvements were authorized under provisions of Section 205 of the 1948 Flood Control Act, as amended. The project, constructed to provide agricultural flood risk management, was completed in November 1973. The improvements consist of channel enlargement and straightening along the Lower Branch of the Rush River. The work extends from mile 17.3 to the confluence with the Sheyenne River.

1.5.3.8 Argusville, ND Levee: The project was authorized under Section 205 of the 1948 Flood Control Act, as amended. Construction was completed in 1990. The flood risk management project consists of about 1.9 miles of earthen levees with an average height of 8 feet that encircle the city of Argusville. This includes sandbag closures at two railroad and four road crossings and raised roadways at three locations. Levees on the north and east sides of the city have a design top elevation of 891.1 feet including 3 feet of freeboard above design flood level. Levees on the south and west sides of the city have a design top elevation of 888.6 feet. The project is designed to provide the city with protection against the estimated 1-percent chance flood event.

1.5.3.9 Halstad, MN Levee: The project was authorized under the provisions of Section 205 of the Flood Control Act of 1948, as amended. The flood barrier consists of 2.41 miles of earthen levee, eight emergency closures and road raises on Trunk Highways 75 and 200. Interior flood control facilities consist of 4 ponding areas with gravity outlets and sluice gates, 464 feet of twin 66-in interceptor pipes and 350 feet of interceptor ditch. Additionally, there are small ditches and drainage swales alongside the toe of the levees. Once the closures are in place the city is provided with flood risk management against a 250-year flood event on the Red River of the North.

1.5.3.10 The Sheyenne River project was authorized by the 1986 Water Resources Development Act. The project originally included four components: a 5-foot raise of the Baldhill Dam flood control pool; a dam on the Maple River to provide approximately 35,000 acre-feet of storage; a 7.5-mile flood diversion channel from Horace to West Fargo, North Dakota; and a 6.7-mile flood diversion channel at West Fargo. The Southeast Cass Water Resource District and the St. Paul District, Corps of Engineers, signed cost-share agreements for the West Fargo Diversion project in 1988 and the Horace to West Fargo Diversion in 1990. The diversion projects were substantially completed in 1993 and 1994. A pump station was added to the West Fargo project in 2003 and emergency generators were provided in 2007. The Maple River dam was de-authorized in 2002 for federal participation, and the Southeast Cass Water Resource District completed the project without federal assistance in 2007. The Maple River dam has a storage capacity of 60,000 acre-feet. These projects reduce flood risk for the cities of Horace and West Fargo and the west side of Fargo from Sheyenne River flooding. From Horace to West Fargo, the system is designed for a 1-percent chance event plus 2 feet. At West Fargo, the channel and left descending bank levee contain the 1-percent chance event plus 2 feet, and the right descending bank levee is higher, providing the city with protection from the Standard Project Flood plus 3 feet. The Standard Project Flood is defined as the volume of streamflow expected to result from the most severe combination of meteorological and hydrologic conditions which are reasonably characteristic of the geographic region involved, excluding extremely rare combinations. Although these features reduce the risk associated with Sheyenne River flooding, these cities are still potentially affected by floods on the Wild Rice and Red Rivers that are larger than approximately a 0.5-percent chance event.

1.5.3.11 A Section 208 (1954 Flood Control Act) clearing and snagging project was completed in Fargo-Moorhead in 1991. The project cleared and snagged trees affected by Dutch elm disease that would otherwise have caused stage increases in the Red River. Dead and dying trees were removed along a 9.7-mile reach of the Red River of the North.

1.5.3.12 Three Section 14 (1946 Flood Control Act) emergency streambank protection projects were completed in Fargo between 2001 and 2003. Erosion from the Red River of the North occurred at three separate project locations. At Reach A, erosion along 4,100 feet of riverbank threatened a levee near 37th Avenue. At Reach B, erosion along a 950-foot reach threatened Kandi Lane and North Broadway and utilities located beneath them. At Reach C, erosion along a 1,900-foot reach threatened Elm Street between 13th and 17th Avenues North and the utilities located beneath it. The erosion progressed to within 50 feet of the roadway. The projects involved shaping the banks and placing rockfill or granular fill and riprap along the eroded areas.

1.5.3.13 Two Section 206 (1996 Water Resource Development Act) aquatic ecosystem restoration projects were implemented to improve fish passage over two dams on the Red River within the metropolitan area. Rock slope fishways were constructed at the 12th Avenue North Dam and the 32nd Avenue South Dam in 2002 and 2004, respectively. A similar fishway was constructed at the Midtown Dam in 1998 without Corps construction assistance.

1.5.3.14 A Section 205 (1948 Flood Control Act) project known as the Fargo-Ridgewood project is located on the north side of Fargo in the Ridgewood area, along the west bank of the Red River of the North. The project consists of levees, floodwalls, pump stations and associated interior drainage structures along a line of protection 4,200 linear feet long. The project is designed to provide flood risk management to the Ridgewood neighborhood and a Department of Veterans Affairs (VA) hospital. The project reduces risk to the Department of Veterans Affairs (VA) hospital and that portion of Fargo between 15th Avenue North and 22nd Avenue North. High ground at the ends of the project is at elevation 899.5 feet. However, the top elevation of the levees is at elevation 902.6 feet. The construction of this project was substantially complete in the fall of 2010. The project successfully provided a line of protection during the March 2010 flood event.

1.5.3.15 Non-federal emergency levees:
Georgetown, MN: The existing levee in Georgetown has a minimum top elevation of 883.3 (NAVD 1988). The levee was raised by the Corps during the 2009 flood. The Corps hired a contractor to restore the dike so that now west of Highway 75 the levee varies from 883.3 to 884.2 (NAVD1988). East of Highway 75, the levee was restored to 884.4. Highwater marks taken after the 1997 flood were used to set the elevation for the levee. There is no written operation plan for this levee. The 23 culverts through the levee are equipped with flapgates and close automatically. The local government places sandbags over these gates to ensure their closure and minimize leakage during large flood events.

Perley, MN: The current system consists of emergency flood levees built in 1970 after extensive damage occurred during the 1969 spring flood. Improvements were made in 1975 and 1997. The levee consists of two reaches and 2 closures. Reach 1 is constructed to elevation 877.5 feet (NGVD 29), and Reach 2 is constructed to elevation 878.4 feet (NGVD 29). The design is to a level of 2 feet above the 1997 flood. Currently the city is working on raising the levee to 3 feet above the 2009 flood.

Hendrum, MN: Two separate reaches were constructed in anticipation of flooding from the Red River in July 1975 and the levee was most recently modified in 1998. The levee consists of 3 reaches and requires 4 closures. The minimum levee elevations for reaches 1, 2, and 3, are 873.7, 873.1, and 873.1 feet, respectively (NGVD 29). The current design is to a level of 2 feet above the 1997 flood. Currently the city is working on raising the levee to 3 feet above the 2009 flood.

Kragnes, MN: After the Spring 2009 flood, most of the project embankments that could be raised were raised. The current elevation of the embankments is 893.5 (NAVD1988). However, Highway 75 provides protection to roughly elevation 892.5 (NAVD1988). The roads in the area - County State Aid Highway (CSAH) 26, County Road 96, and Highway 75 - provide most of the embankments that protect Kragnes. The pipes through these roads have been installed with screwgates to prevent water from flowing into the triangular area formed by these three roads. In general, to provide protection in excess of 892.5 (NAVD1988) requires building embankments along the roads. County Road 96 provides protection that is slightly higher than this elevation and CSAH 26 is a few feet higher than CR 96. The Highway 75 overtopping elevation had to be raised by building a clay embankment along a stretch of the east shoulder in the spring of 2009 to prevent the floodwaters from overtopping the highway to the west. Water breaks out of the Buffalo River and floods northwesterly toward Kragnes. 2009 is the first flood that would have overtopped Highway 75 between CSAH 26 and CSAH 5.

Shelly, MN: The city's levee system consists of two reaches. Reach 1 is a 2000 foot levee constructed to an elevation 868.8 (NGVD 29). It protects the property north of Highway 3 that runs through town. Reach 2, which is 545 feet long, protects the portion of the city located south of Highway 3. Reach 2 is constructed to an elevation of 867.0 feet (NGVD 29). The last modification to this system was made in 1999 and the design is to a level of 2 feet above the 1997 flood. However, the levee does not encircle the town and fill needs to be placed to complete the protection. The city is currently contemplating raising the level of protection to 3 feet above the 2009 flood.

Harwood, ND: The city's levee system consists of two main reaches and several smaller reaches along Interstate 29, including one sandbag closure and a breach controlled section. The system provides protection up to a flood elevation of 892.8 (NAVD88). When the flood elevation reaches 891.0 (NAVD88) and is projected to reach above the elevation of 892.8, additional work is done within the I-29 right-of-way. The highest record peak flood elevation on the Sheyenne River at Harwood, ND was 892.02 (NAVD88) in April of 1997.

Oxbow, ND: The city's levee system consists of several reaches designed to reduce risk of flooding directly from the Red River as well as through the golf course. The top of the levee system ranges from 917 feet to 918 feet (NAVD88). Operation requires closing of a number of openings with either clay or sandbags. The highest record peak flood elevation at Oxbow occurred in March of 2009 was approximately 916 feet (NAVD88). Oxbow's flood risk reduction system is not designed to remove any structures or property from the 1-percent chance event floodplain.

1.5.3.16 Other non-Federal projects. There are a number of local retention projects that have been constructed upstream of the study area including: Three dams constructed on the upper portion of the Wild Rice River, Dead Colt Creek Dam on a tributary of the Sheyenne, the T-180 dam on a tributary of the Maple, three dams on tributaries of the Maple River, Erie Dam located on the upper portion of the Rush River, and three dams located on Elm River.

1.6 PLANNING PROCESS AND REPORT ORGANIZATION

The planning process consists of six major steps which are generally taken in order and are an iterative process. The steps are: (1) Specification of water and related land resources problems and opportunities; (2) Inventory, forecast and analysis of water and related land resources conditions within the study area; (3) Formulation of alternative plans; (4) Evaluation of the effects of the alternative plans; (5) Comparison of the alternative plans; and (6) Selection of the recommended plan based upon the comparison of the alternative plans.

The chapter headings and order in this report generally follow the outline of an Environmental Impact Statement. Chapters of the report relate to the six steps of the planning process as follows:

- The second chapter of this report, Need for and Objectives of Action, covers the first step in the planning process (Specification of water and related land resources problems and opportunities).

- The third chapter of this report, Alternatives, is the heart of the report and is therefore placed before the more detailed discussions of resources and impacts. It covers the third step in the planning process (Formulation of alternatives), the fifth step in the planning process (Comparison of alternative plans), and the sixth step of the planning process (Selection of the recommended plan based upon the comparison of the alternative plans).

- The fourth chapter of this report, Affected Environment, covers the second step of the planning process (Inventory, forecast and analysis of water and related land resources in the study area).

- And, the fifth chapter of this report, Environmental Consequences, covers the fourth step of the planning process (Evaluation of the effects of the alternative plans).

2.0 NEED FOR AND OBJECTIVES OF ACTION *

This chapter presents the results of the first step of the planning process, the specification of water and related land resources problems and opportunities in the study area. The chapter concludes with the establishment of planning objectives and planning constraints, which is the basis for the formulation of alternative plans.

2.1 NATIONAL OBJECTIVES

The national or federal objective of water and related land resources planning is to contribute to national economic development consistent with protecting the nation's environment, pursuant to national environmental statutes, applicable executive orders and other Federal planning requirements. Contributions to national economic development (NED) are increases in the net value of the national output of goods and services expressed in monetary units. Contributions to NED are the direct net benefits that accrue in the planning area and the rest of the nation as a result of the project.

The Corps has added a second national objective for Ecosystem Restoration in response to legislation and administration policy. This objective is to contribute to the nation's ecosystems through ecosystem restoration, with contributions measured by changes in the amounts and values of habitat.

2.2 PUBLIC CONCERNS

A number of public concerns have been identified during the course of the study. Initial concerns were expressed in the non-federal sponsors' study request. Additional input was received through coordination with the sponsors, coordination with other agencies, public review of draft and interim products, and through public meetings. A discussion of public involvement is included in Chapter 6, Public Involvement, Review and Consultation. The public concerns that are related to the establishment of planning objectives and planning constraints are as follows:

- Flooding and impacts to rural and urban infrastructure
- Potential for flood risk management measures employed in one place to increase flood stages or impact water quality elsewhere
- Desire for additional flood storage in the watershed
- Desire for wetland and grassland restoration in the watershed
- Desire for increased recreational opportunities in the study area
- Need to protect limited groundwater resources
- Need to protect riverine habitat and connectivity

2.3 HISTORY AND FUTURE WITHOUT PROJECT CONDITIONS

2.3.1 Flood History

The Fargo-Moorhead metropolitan area has a relatively high risk of flooding; average annual flood damages in the metropolitan area are estimated at more than $194.8 million (see Appendix C, Economics). The highest river stages usually occur as a result of spring snowmelt. Summer rainfall events have also caused significant flood damages, although this flooding is usually related to the capacity of the storm sewer system rather than high river stages.

The Red River of the North has exceeded the National Weather Service flood stage of 18 feet in 48 of the past 109 years, and every year from 1993 through 2011. The study area includes the Buffalo River, Wild Rice River (ND), the Sheyenne River and the Red River of the North as shown in Chapter 1, Figure 1; interbasin flows complicate the hydrology of the region and contribute to extensive flooding. The record-setting Red River of the North flood stage in 2009 at Fargo was 40.82 feet on the Fargo gage.

Official estimates vary for the 1-percent chance event flow and stage. The current base flood elevation (1-percent chance event) established by the Federal Emergency Management Agency (FEMA) corresponds to a stage of 38.3 feet on the Fargo gage. FEMA is proposing a revised 1-percent chance event flow of 29,300 cubic feet per second (cfs) and stage of 39.3 feet based on flood insurance studies completed after the 1997 flood event. The hydrologic record of the Red River of the North shows a trend of increasing magnitude and frequency of flooding in recent decades. Figure 7 shows the natural annual maximum mean daily flow on the Red River at Fargo for the period of record. Figure 8 shows annual peak stages for the period of record.

Figure 7 – Natural annual maximum mean daily flow on the Red River at Fargo

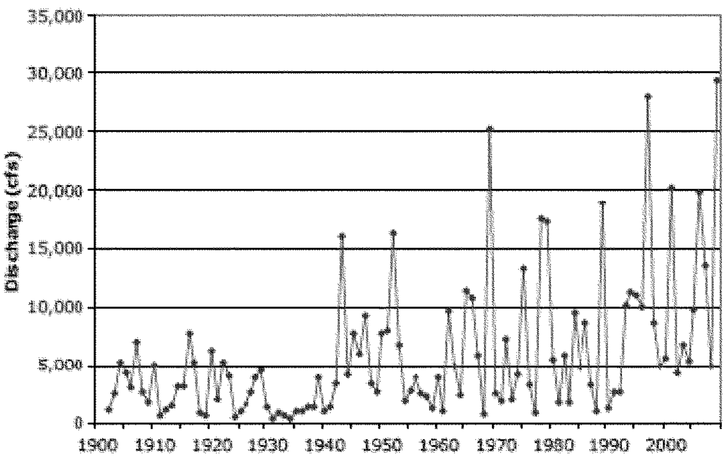
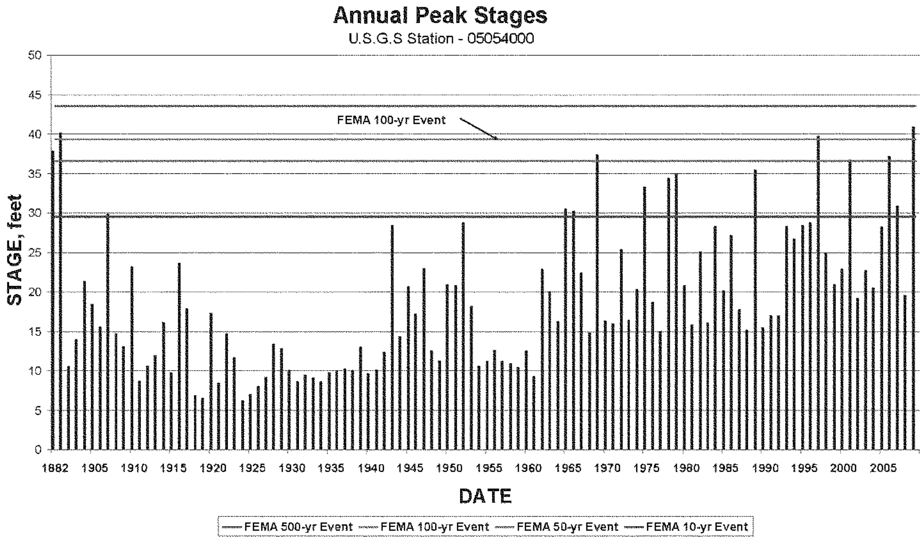


Figure 8 – Annual peak stages on the Fargo gage (Gage 0 = elev. 862.74 NAVD 1988)



A panel of experts in hydrology and climate change was convened to elicit opinions on how to appropriately reflect this trend in the current analysis (see Appendix A, Hydrology). The panel concluded that the hydrologic record showed a "dry" period in the early decades and a "wet" period in later years continuing to the present. The panel recommended developing revised flow frequency curves separately for the dry and wet periods and then combining the curves using probabilistic assumptions about future conditions. On the basis of the panel's recommendations, revised flow frequency curves were developed which show the 1-percent chance event flow to be approximately 34,700 cfs at present; 32,900 cfs in 2035; and 31,300 cfs in 2060. The hydraulic modeling developed for this feasibility study and calibrated to the 2009 flood event indicated that a flow of 34,700 cfs at the Fargo gage would produce a stage of 42.4 feet (See Appendix B, Hydraulic Engineering). The analyses described in Section 3.4 of this report were based upon the Expert Opinion Elicitation (EOE) panel's hydrologic recommendations, which result in significantly higher stages for the 1-percent chance event than what FEMA is proposing to use for the National Flood Insurance Program.

Figure 9 through Figure 12 show the proposed FEMA 10, 50, 100 and 500-year existing flooded areas truncated to the area inside the proposed diversion alignments. Note: the following figures illustrate the areas potentially benefited by the project, but they do not show the entire floodplain in the study area. This was done to focus on the benefits the project would provide to the Fargo-Moorhead Metropolitan area.

Figure 9 – Existing 10-Year floodplain (10-percent chance)

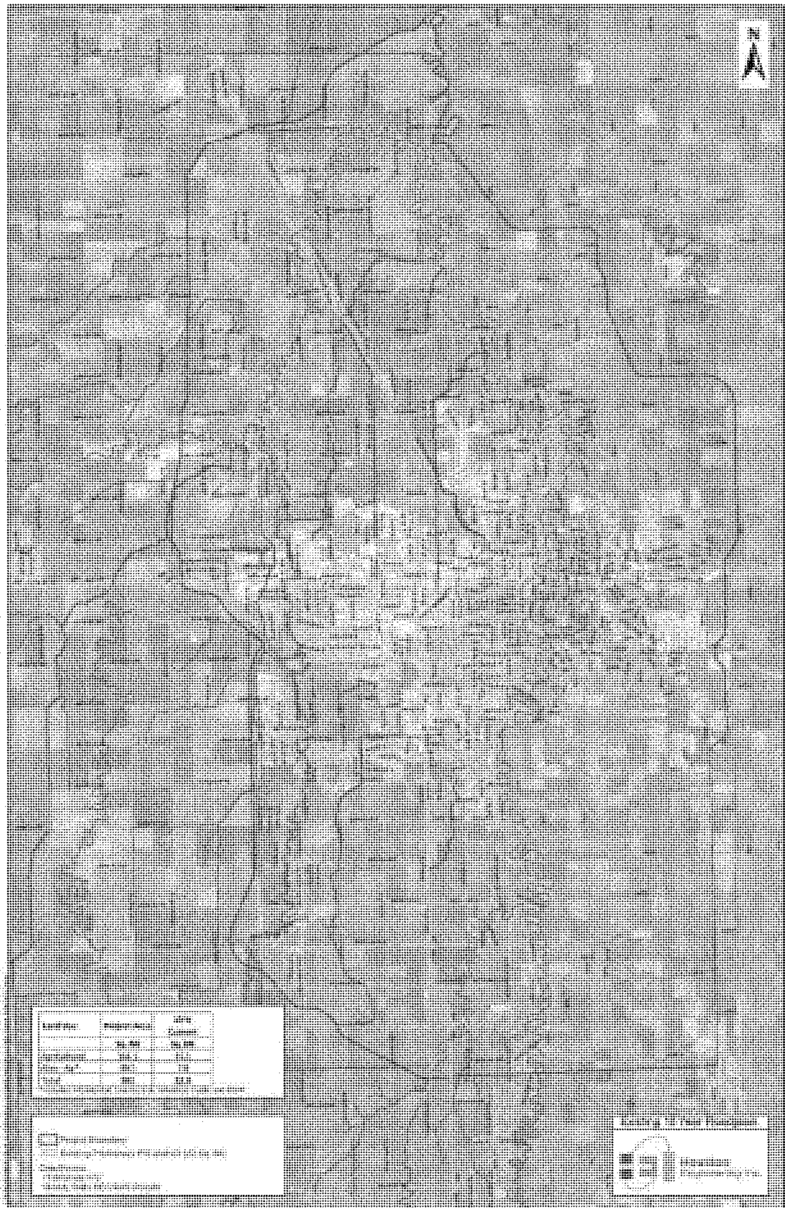


Figure 10 – Existing 50-year floodplain (2-percent chance)

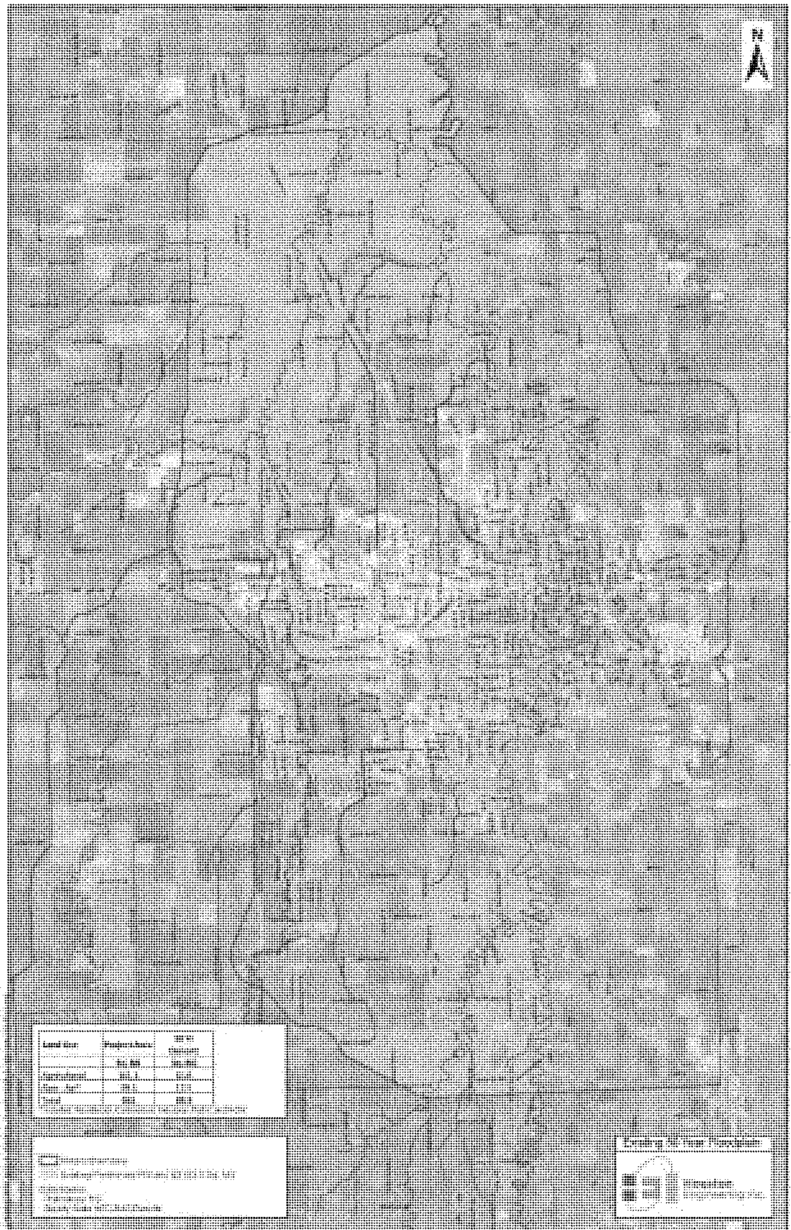
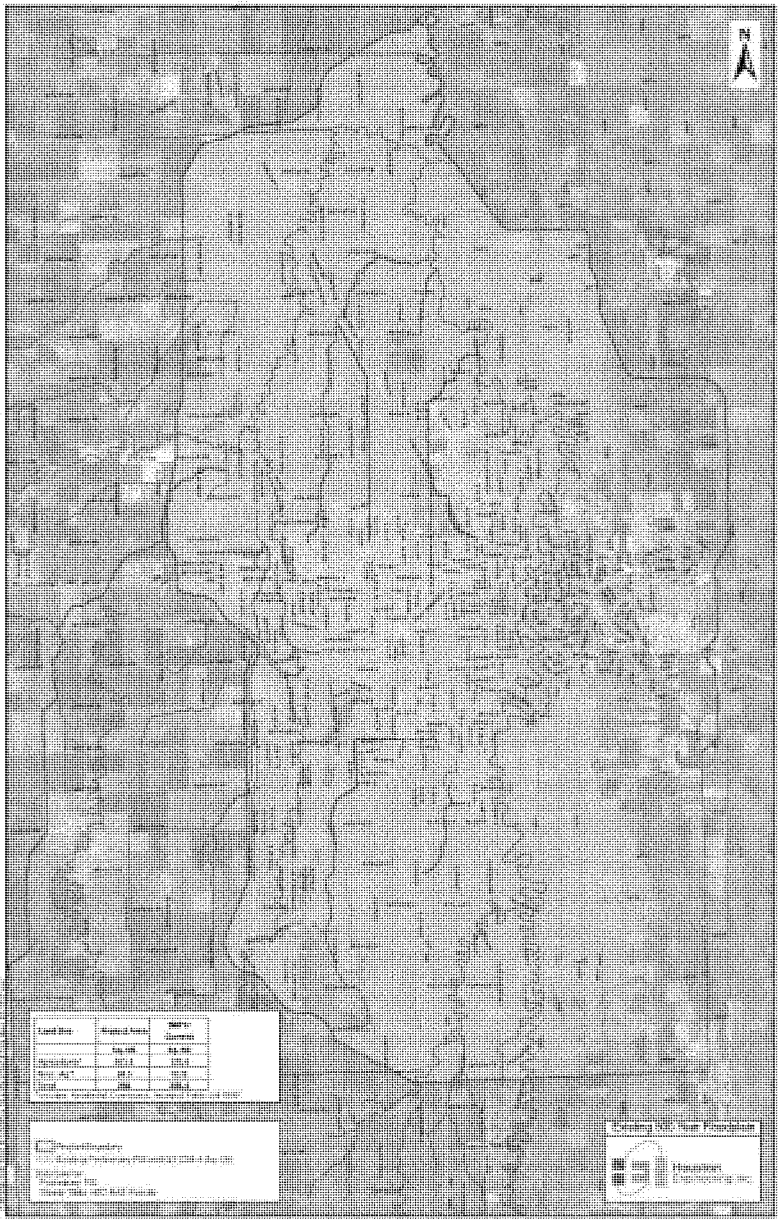


Figure 11 – Existing 100-year floodplain (1-percent chance)

Figure 12 - Existing 500-year floodplain (0.2-percent chance)



2.3.2 Existing infrastructure

Existing projects in the study area are described earlier in this report in Section 1.5, Prior Reports and Existing Projects. The information below supplements the earlier discussion. Information related to existing levees including photos and locations can be found in Appendix H.

Flood impacts in Fargo begin at a stage of about 18 feet, when Elm Street is closed to traffic. The city of Fargo's existing levees have top elevations that vary from a stage of 30 feet to 42 feet, but most reaches are at or below 37 feet. The Second Street area near Fargo City Hall begins to flood at a stage of approximately 30 feet, and emergency levees have been built there 12 times since 1969. Many places along the line of protection rely on private sandbag levees which begin to be needed at a stage of about 33 feet, with an exceedence frequency between 10-percent and 20-percent. Newer developments in the southern part of the study area have been elevated above the base flood elevation, but the city infrastructure (roads, sewers, etc.) is still at risk.

Rural areas and developed subdivisions in Cass County, North Dakota are susceptible to flooding from the Sheyenne, Maple, Rush, Lower Rush, Wild Rice and Red Rivers. During the 2009 flood, many homes north and west of Fargo were surrounded by flood waters. Although most structures in this area were elevated above the flood level and escaped major damage, residents were not able to access their homes for up to six weeks except by boat. The rural road network was significantly damaged by overland flows that washed out portions of roads. There were approximately 200 damage sites on the Cass County highway system and 1000 damage sites on the township road system in Cass County. Cities and subdivisions south of Fargo, including the cities of Briarwood, Chrisan, Forest River, Heritage Hills, Hickson and Oxbow were also at risk of flooding from the Wild Rice and Red Rivers. Private sandbag levees and emergency clay levees constructed by the Corps of Engineers protected many areas, but the areas closest to the rivers were hard hit. Significant damage occurred to five of 27 homes in Briarwood, 60 homes in the Chrisan and Heritage Hills area, seven of fourteen homes in Butch-R-Block subdivision, and fifteen of 140 homes in Oxbow.

The West Fargo and Horace to West Fargo diversions of the Sheyenne River Flood Control Project, completed in 1994, prevented breakout flows from the Sheyenne River from flooding Fargo and West Fargo in 1997, 2009 and 2010. While these existing diversions provide significant benefit from Sheyenne River flooding, Horace and West Fargo are vulnerable to flooding from the Red River during events larger than the 1-percent chance (100-year) event.

The city of Moorhead sits on relatively higher ground compared to Fargo. At a stage of 31 feet, Moorhead's First Avenue North is closed. Homes begin to be threatened at stages of 32 to 35 feet. Most of Moorhead's developed areas are above the proposed FEMA 1-percent chance flood stage, but the 0.2-percent chance event floodplain south of Interstate 94 (I-94) extends east almost to 20th Street South. North of I-94 the 0.2-percent chance event floodplain generally extends to east of 14th Street. During flood events larger than a 1-percent chance event, it is anticipated that I-94 would be inundated, eliminating a major thoroughfare and possible evacuation route. Moorhead has no permanent federal flood risk management project. Most of the land along the river is residential development, and private sandbag levees or other private measures provide most of the line of protection. Flooding through the sanitary sewer system is a significant concern in Moorhead, because several residences have walkout basements adjacent to the river. If these basements are flooded, water can enter the sanitary sewer and affect homes far from the surficial floodplain. Flooding from the Buffalo River to the east of Moorhead is not a significant concern in the city. Drainage projects in this area have been improved to address any historic flooding issues.

Oakport Township (population 1,689) is located north of Moorhead. Oakport sustained $3.7 million in damages in the 1997 flood. High water from the Red River of the North and Oakport Coulee damaged 150 homes and isolated 200 others. Oakport was severely affected during the 2009 flood as well. The Buffalo-Red River Watershed District is currently constructing a permanent levee system with a top elevation three feet above the 2009 event, which is expected to be certifiable to the 1-percent chance level. Portions of Oakport Township will be annexed by the City of Moorhead in 2015.

Since the 1997 flood, Fargo and Moorhead have implemented mitigation measures, including acquisition of floodplain homes, building levees and floodwalls, raising and stabilizing existing levees, installing permanent pump stations and improving storm sewer lift stations and the sanitary sewer system. Moorhead has a list of several low elevation properties adjacent to the river that it would like to buy to install higher levels of flood risk management; to date, 65 properties have been purchased. Moorhead has a draft plan for a voluntary program for assistance to build private levees/floodwalls, but reaction to the proposed program has been mixed, and the city has not yet officially adopted it. Fargo maintains a prioritized list of potential buyouts and actively seeks to purchase and remove floodplain homes. Fargo has purchased 125 homes from willing sellers since 1997. Fargo also adopted a flood risk management incentive program in 2006 and amended it in 2009. The program provides for a cost share of up to 75-percent by the city in improvements made by the individual homeowners to improve their level of flood risk management. The homeowner must enter into an elevation agreement to be eligible.

The Department of Veterans Affairs and the city of Fargo worked with the Corps of Engineers to construct a floodwall and levee system in the Ridgewood neighborhood of Fargo, which is discussed in Section 1.5.3.14 of this report.

2.3.3 Flood fighting activities

The Fargo-Moorhead area has become accustomed to dealing with flooding. Time is usually available to prepare for flood fighting because winter snowfall can be monitored to predict unusual spring runoff. The time required to build emergency works depends on the anticipated flood crest elevation, with higher crests requiring significantly more construction time and effort. Fargo and Moorhead have well-documented standard operating procedures for flood fights. Both communities avoided major flood damages in the historic floods of 1997 and 2009 through the use of extreme emergency measures. These emergency measures included such actions as temporarily raising existing levees, constructing temporary levees and floodwalls in various areas, and sandbagging.

The residents of Fargo-Moorhead have been successful at preventing significant damages during past flood events by constructing emergency levees along large portions of the Red River. Constructing the emergency levees takes significant financial and human resources, causes business and traffic disruptions and is taxing to the social fabric of the communities. Although the emergency levees have been successful in the past, there is a high risk of a catastrophic failure which would result in significant damages and loss of life to the area.

Significant costs are incurred during emergency flood fighting efforts. During large flood events, the cities build as many as 80 miles of emergency levees through town in an effort to retain flood waters. Businesses, residents, federal agencies, local and state governments, as well as humanitarian organizations such as the Red Cross and Salvation Army all contribute to the flood fight, rescue and clean-up efforts. These costs are estimated to be $2,883,000 on an average annual basis.

During the 2009 flood, more than 80 miles of temporary protection measures were built in less than two weeks, including the placement of more than three million sandbags by thousands of volunteers. Picture 1 through Picture 6 show the conditions and flood fighting activities that took place during the 2009 flood event.

Picture 1 – Thousands of residents from the region assisted with building miles of sandbag levees in 2009

Picture 2 – Various temporary measures were used as barriers in difficult winter conditions in 2009

Picture 3 – Citizens set up steel frames to hold back the water in 2009

Picture 4 – Roads were closed throughout the region, making travel difficult in 2009

Picture 5 – Agricultural lands, sport facilities, and public areas were dug up for levee material in 2009

Picture 6 – Sand filled barriers were backed with clay and used as a second line of defense after the sandbags in 2009

Floods in the Fargo-Moorhead area typically occur in late March and early April. During this time, temperatures vary from sub-zero (°F) to well above freezing. In March the average monthly temperature is 27.2 °F, with an average daily high of 35.3 °F and an average daily low of 19.0 °F. In April the average monthly temperature is 43.5 °F, with an average daily high of 54.5 °F and an average daily low of 32.4 °F. The ground is still frozen, with average frost penetration estimated at about 4.5 feet in early April. The extreme range of temperatures results in varying precipitation conditions ranging from blizzards with heavy snowfall to soaking rains.

These conditions impede flood fighting by hampering earth-moving and levee construction. Emergency levees must often be constructed on frozen ground with frozen materials. Many portions of the line of protection are located in private yards with little or no access for construction equipment. Borrow sites for clay material become inaccessible when the soil is saturated by melting snow or rain. The logistics required for successful emergency actions under these conditions cannot be overestimated.

The extremely variable weather conditions also complicate efforts of the National Weather Service to predict the flood crest. Accurate crest predictions are needed to establish the elevation of emergency levees, but it is difficult to anticipate rates of snowmelt and effects of additional precipitation when temperatures hover around the freezing point. There is considerable uncertainty surrounding every crest prediction. Both the 1997 and 2009 flood events were affected by sudden cold snaps that served to temporarily halt melting and likely contributed to lower peak stages than would have occurred if slightly warmer temperatures had prevailed.

Because emergency measures have been very successful in the past, they may also contribute to an unwarranted sense of security that does not reflect the true flood risk in the area. History has shown that the people in the study area will stay to fight a flood rather than evacuate to safer locations. A loss of life analysis conducted for this feasibility study estimated that as many as 200 people could perish if emergency levees failed suddenly during a 1-percent chance event (See Appendix O, Plan Formulation). Flood water would be extremely cold, just above freezing, and anyone caught in the water would suffer hypothermia in a short time.

Due to all of the factors mentioned above, the probability of having consistently successful emergency efforts in the future must be considered extremely low, especially for events larger than the 1-percent chance event. However, it is acknowledged that the probability of success with an emergency flood fight is not zero. To account for this, a sensitivity analysis was performed to determine how successful flood fights could impact the project benefits. (See Appendix C, Economics.)

Although the economic analyses conducted for this study assumed no credit for emergency actions, credit was given to existing permanent levees in accordance with applicable Corps of Engineers guidance. (See Appendix H, Credit to Existing Levees.)

2.3.4 Future Without Project condition (No Action alternative)

Without a comprehensive flood risk management project in the area, the metropolitan region will continue to be subject to flooding and will rely on emergency responses to ensure the safety of the community. These emergency efforts will eventually be overwhelmed, and the area could experience a disaster similar to the 1997 flood in Grand Forks and East Grand Forks. A disaster of that magnitude would cause significant damage and would impact the entire region. It is expected that the average annual damages of more than $194.8 million will continue and increase as a result of additional development between the 1-percent chance and 0.2-percent chance flood elevations.

The Oakport, MN levee project is the only major levee project that will be completed in the metropolitan area in the near future. The city of Fargo has developed plans for a Southside levee project, however those plans have been put on hold indefinitely, pending the outcome of this feasibility study. It is possible that without a federal project the Southside levee plan could be pursued in the future, but it would face many challenges before being realized. It is assumed that the Southside project is not in place for the future without-project condition. This is consistent with guidance in IWR 88-R-2, National Economic Development Procedures Manual - Urban Flood Damage, Volume 1, Page VI-3, paragraph 6 which states: "If local action is planned to occur only as the result of no federal action, the project should not be assumed as part of the "without" condition. Local interests should not be penalized for their own incentive."

It is anticipated that the metropolitan communities will continue to use best practices and make minor modifications to enhance their overall flood risk management whenever possible. This includes construction of short sections of levees and floodwalls that do not tie into high ground but would be augmented with emergency measures. Communities downstream on the Minnesota side, including Georgetown, Perley and Hendrum, are planning to construct levees to bolster their flood defenses if funding for the projects can be obtained.

Local communities and the Corps are also evaluating efforts to reduce flood stages through upstream water storage. Phase 1 of the Corps' Fargo-Moorhead and Upstream feasibility study determined that stage reductions up to about 1.6 feet could be obtained using storage during a 1-percent chance event, but the economic benefits would not likely support federal participation solely for flood risk management. The study is now considering the potential for ecosystem restoration and looking for synergistic solutions to both flooding and historic loss of native aquatic habitat. It is anticipated that some impoundments will be constructed by non-federal entities in the upstream watershed, however, reductions to flood stages in the Fargo-Moorhead area would be relatively small. For purposes of this feasibility study and evaluating the economics of alternatives, we cannot assume that upstream flood retention will be built in the future to a sufficient extent to significantly reduce the flood risk in the study area.

<u>2.3.5 Environmental conditions</u>
Existing and expected future environmental conditions are discussed in detail in Chapter 4, Affected Environment. The Red River basin lies within the Prairie Pothole Region, which has been dramatically affected by drainage and tillage predominantly related to this region's urban development and agriculture-based economy. According to the 1997 Minnesota Wetlands Conservation Plan, over 95 percent of the native wetlands in the Minnesota portion of the Fargo-Moorhead and upstream subbasin have been lost. The North Dakota portion of the study area has also experienced a similar amount of lost wetlands. The resulting habitat loss has caused a

dramatic decline in wetland-dependent wildlife populations. Because the Red River basin lies within a major waterfowl and shorebird migration route, the loss of permanent and seasonal wetlands has had a measurable adverse impact on migratory success.

There are numerous wetland restoration programs within the Red River Basin, but implementation has often been hindered by cost and/or land availability. The objectives of the wetland restoration programs include providing flood storage, improving water quality, and increasing wildlife and recreation opportunities.

Due to increasing pressure to either urbanize or improve drainage on cropland, it is anticipated that wetland acreage will either remain the same or decrease within the study area under the without project condition.

Upland habitat in the study area is mainly cropland, with a mixture of hayed pasture, hobby farms and suburban dwellings. Wooded areas include mostly a mixture of bottomland hardwood tree species and low vegetation. The narrow riparian zone is in a relatively natural condition. The remaining wooded riparian areas are an important wildlife and aesthetic resource. The riparian woodlands are essentially the only wooded habitat remaining in this predominantly agricultural area. Tree species identified in these areas include bur oak, American linden, eastern cottonwood, American elm, boxelder, green ash, silver maple, buckthorn, and hackberry. Woodland was never very common in the prairie environment, but it is extremely important as nesting, breeding, and overwintering habitat for a number of birds, mammals, and reptiles.

2.4 PROBLEMS AND OPPORTUNITIES

The evaluation of public concerns reflects a range of needs and desires perceived by the public. This section describes these needs in the context of problems and opportunities that can be addressed through water and related land resource management. The problems and opportunities are based upon the flood history and future without project conditions.

2.4.1 Problems

The primary problem identified in the study area is a high risk of flood damage to urban infrastructure from the Red River of the North, the Wild Rice River (ND), the Buffalo River, and the Sheyenne River and its tributaries, the Maple River, Lower Rush River and Rush River. Flooding also causes damage to rural infrastructure and agricultural land and disrupts transportation and access to properties within the study area. The study area has estimated average annual flood damages of more than $194.8 million.

2.4.2 Opportunities

There are opportunities to increase and improve wildlife habitat in conjunction with the measures used to reduce flood risk. Wildlife habitat in the study area has been significantly altered by various human activities associated with conversion of native prairie for agricultural uses and urban development.

Flood risk management measures that involve land use changes could provide opportunities to increase recreation in conjunction with reducing flood risk.

2.5 PURPOSE AND NEED

The purpose of the proposed action is to reduce flood risk, flood damages and flood protection costs related to the flooding in the Fargo-Moorhead Metropolitan Area.

2.6 PLANNING OBJECTIVES

The national objectives are general statements that are not specific enough for direct use in plan formulation; maximizing national economic development (NED) and restoring ecosystem functions are the overarching goals for this study. The water and related land resource problems and opportunities identified in this study are stated as specific planning objectives to provide focus for the formulation of alternatives. These planning objectives reflect the problems and opportunities in the study area and represent desired positive changes from the future without-project conditions. The planning objectives are specified as follows:

- Reduce flood risk and flood damages in the Fargo-Moorhead metropolitan area.
- Restore or improve degraded riverine and riparian habitat in and along the Red River of the North, Wild Rice River (North Dakota), Sheyenne River (North Dakota), and Buffalo River (Minnesota) in conjunction with other flood risk management features.
- Provide additional wetland habitat in conjunction with other flood risk management features.
- Provide recreational opportunities in conjunction with other flood risk management features.

2.7 PLANNING CONSTRAINTS

Unlike planning objectives that represent desired positive changes, planning constraints represent restrictions that should not be violated. The planning constraints identified in this study are as follows:

- Avoid increasing peak Red River flood stages, either upstream or downstream
- Comply with the Boundary Waters Treaty of 1909 and other pertinent international agreements.
- Avoid negatively impacting the Buffalo Aquifer in Minnesota.
- Minimize loss of floodplain in accordance with Executive Order 11988, Floodplain Management

2.8 NATIONAL ECONOMIC DEVELOPMENT (NED) PLAN

Federal policy requires that the feasibility study must identify the plan that reasonably maximizes net national economic development (NED) benefits consistent with protecting the environment. That plan, the "NED plan," must be recommended for implementation unless there are overriding reasons for recommending another plan based on other Federal, State, local and international concerns. A different plan may be recommended as a "locally preferred plan" if it has positive net economic benefits and is approved by the Assistant Secretary of the Army for Civil Works (ASA(CW)).

3.0 ALTERNATIVES*

This chapter describes the development of alternative plans that address the planning objectives, the comparison of those plans and the selection of a plan. It also describes the selected plan and its implementation requirements.

3.1 PLAN FORMULATION RATIONALE

A wide variety of management measures were developed that would address one or more of the planning objectives. These measures were evaluated and then screened. Alternative plans were then developed which comprised of one or more of the management measures.

3.2 MANAGEMENT MEASURES AND PRELIMINARY PLANS

3.2.1 No Action

The Corps is required to consider the option of "No Action" as one of the alternatives in order to comply with the requirements of the National Environmental Policy Act (NEPA). With the No Action alternative, which is synonymous with the "Without Project Condition," it is assumed that no project would be implemented by the federal government to achieve the planning objectives. The No Action alternative forms the basis against which all other alternative plans are measured. The No Action alternative was described in detail in Chapter 2. Critical assumptions in defining the no action alternative include:

- Emergency flood fighting activities would continue to occur
- Emergency flood fighting measures have low reliability
- A failure of emergency measures could result in loss of life
- Urban areas will expand into the floodplain
- Development in the floodplain will comply with floodplain regulations; floodplain development will be elevated above the FEMA 1-percent chance event in accordance with local standards
- Equivalent expected annual damages greater than $194.8 million will continue

3.2.2 Measures to address identified planning objectives

A management measure is a feature or activity at a site which addresses one or more of the planning objectives. Several alternative measures were identified for consideration in evaluating future possible actions in the Fargo-Moorhead Metropolitan Area. Direct input provided during the reconnaissance and feasibility phases from sponsors and stakeholders, at public meetings and through written public comments, provided a wide array of potential measures. Each measure was assessed using screening criteria (see section 3.4.2), and a determination was made regarding whether it should be retained in the formulation of alternative plans.

3.2.2.1 Non-structural measures reduce flood risk by modifying the characteristics of the buildings and structures that are subject to floods or modifying the behavior of people living in or near floodplains. In general, non-structural alternatives do not modify the characteristics of floods nor do they induce development in a floodplain that is inconsistent with reducing flood risk. Some non-structural measures that can be formulated into non-structural alternatives include removing buildings from floodplains by relocation or acquisition; flood proofing buildings; placing small levees, berms or walls around buildings; implementing flood warning and preparedness activities; and implementing floodplain regulation. The National Flood Insurance Program (NFIP) is considered among non-structural alternatives since it contains programs to provide minimum standards for floodplain regulation, to provide flood insurance, and to provide flood hazard mitigation. Many non-structural measures are already in place throughout the study area, primarily in newer developments built in accordance with floodplain regulations. The Corps must develop and present at least one plan that is primarily non-structural in nature. Non-structural measures will also be considered for integration with structural measures to maximize effectiveness of all alternatives.

3.2.2.2 Structural measures reduce flood risk by modifying the characteristics of the flood; they are often employed to reduce peak flows (flood storage), direct floodwaters away from damageable property (flood barriers), or facilitate the flow of water through or around an area (channel modifications or diversions). Several structural measures have already been implemented to provide benefits to the study area, as described earlier in this report.

3.2.2.3 The measures that were considered in this study are listed below. Detailed descriptions of the measures are included in Appendix O, Plan Formulation.

- No Action: Continue emergency measures

- Non-structural measures
    - Buy and relocate flood-prone structures
    - Flood proofing
    - Elevate structures
    - Flood warning systems
    - Flood insurance
    - Wetlands
    - Grasslands
    - Pay landowners for water retention

- Flood barriers
    - Levees
    - Floodwalls
    - Invisible floodwalls
    - Gate closures
    - Pump stations

- Increase conveyance
    - Diversion channels around the study area
        - In Minnesota
        - In North Dakota
    - Increase conveyance in Oakport Coulee
    - Cutoff channels (to short-cut existing meanders)
    - Flattening the slopes on river bank

  - Replacing bridges
  - Underground tunnels
  - Interstate 29 viaduct
  - Dredge river deeper and wider

- Flood storage
  - Large dams upstream
  - Distributed storage
  - Controlled field runoff
  - Storage ponds, also used for water conservation

3.3 FEASIBILITY PHASE 1

3.3.1 General

This feasibility study was conducted in an iterative fashion. A wide array of potential measures was identified during the reconnaissance phase and expanded during the feasibility study. As the study progressed, additional data were produced that allowed the narrowing of alternatives. The planning steps of formulating, evaluating and comparing alternative plans were accomplished iteratively as information about the alternatives was developed.

3.3.2 Phase 1

Feasibility Phase 1 occurred from September 2008 through May 2009. In Phase 1 the study team gathered information to assess existing conditions in the study area and worked to understand the potential for economic justification of a large regional flood risk management project. Hydraulic models were built to determine expected water surface elevations for a full range of possible flood events. A structure inventory was conducted focusing on both residential and commercial structures within the study area. This information was used to calculate expected annual flood damages without federal action. Conceptual designs and cost estimates were prepared for two structural alternatives: a diversion alternative without a control structure and a levee/floodwall alternative. In March 2009 the study area experienced the flood of record, which produced a maximum stage of 40.8 feet on the Fargo gage. The results of the preliminary study were released in May 2009. The preliminary analyses indicated that a levee plan could be economically justified. The preliminary diversion plan was shown to be very effective at reducing flood stages, but it was not cost-effective. Additional study was needed to refine these alternatives. On the basis of this preliminary information, and in the wake of the record-setting flood of 2009, the study team decided to continue planning efforts.

3.4 FEASIBILITY PHASE 2, SCREENING #1

3.4.1 General

Feasibility Phase 2, Screening #1 occurred from May 2009 through November 2009. The study team performed cursory technical analysis of all proposed measures and developed screening criteria to focus evaluation and design efforts on the most implementable alternatives. Preliminary results were presented at public meetings in October 2009. Phase 2 activities included updating both the hydrologic record and hydraulic modeling to reflect the 2009 event However, since the updated information was not available for use during the first screening,

screening #1 analyses were based on Phase 1 traditional hydrology (without the 2009 flood event) and steady-state hydraulic modeling calibrated to the 2006 flood event.

3.4.2 Screening criteria

Corps planning guidance requires that plans be evaluated against four criteria listed in the United States Water Resources Council's Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G): completeness, effectiveness, efficiency and acceptability. Other criteria deemed significant by participating stakeholders are also used to evaluate alternatives. The screening criteria represent the most critical factors to be considered in selecting plans for further evaluation. The following criteria were used to assess the overall characteristics of each alternative measure to identify those most likely to meet the project purpose and objectives.

Effectiveness: Whether the measure or alternative would be effective in maintaining an acceptable level of flood risk management for the Fargo-Moorhead Metropolitan Area. This is one of the P&G criteria. The team assessed conceptual measures for their potential to contribute substantially to the overall effectiveness of any alternative.

Environmental Effects: Direct and indirect effects of natural resources and cultural resources. Direct effects are those effects associated with the construction. Indirect effects are those effects that occur as a result of a change in environmental conditions resulting from the construction or operation of the project. This criterion is related to the planning objectives to restore or improve riverine, riparian and wetland habitat, and a desire to minimize environmental impacts and produce an environmentally sustainable project. It is also a component of overall effectiveness.

Social Effects: Direct and indirect effects on socio-economic resources such as transportation, regional growth, public safety, employment, recreation, public facilities, and public services. This criterion is a component of overall effectiveness.

Acceptability: Controversy and potential effects on community cohesion and compliance with policy are indicators of acceptability. This criterion is one of the P&G criteria.

Implementability: This criterion considers the existence of significant outstanding technical, social, legal or institutional issues that could affect the ability to implement the alternative. This is related to the P&G criterion for acceptability.

Cost: The first cost of the project, costs of local operations and maintenance and long-term residual costs. Cost is related to two P&G criteria: efficiency and acceptability. Cost alone is not used to eliminate any alternatives, but is considered in relation to the other criteria.

Risk: The uncertainties, vulnerabilities and potential consequences of the alternative. Risk is related to the P&G criteria of effectiveness and acceptability.

Separable Mitigation: This criterion considers the potential need for mitigation resulting from the project's implementation to address environmental, hydraulic or other impacts. Is mitigation possible and how does it impact the project cost? This criterion is related to all four of the P&G criteria.

Cost Effectiveness: This criterion is a comparison of expected economic benefits and estimated costs for each alternative and between alternatives. This is a primary consideration in determining whether there is a federal interest in the project, and to what extent federal participation can be justified. This is a component of the P&G criteria of efficiency.

3.4.3 Screening #1 Process

Using the preliminary technical information, the team applied professional judgment in order to assess the measures against the screening criteria. Those measures that appeared to be most viable were refined and further developed so that accurate costs and economic benefits could be determined. Several different scales of non-structural measures, flood barriers and diversion channels were evaluated during this phase of study. The initial diversion channel concept referred to in Section 3.3.2 was improved upon to make it a more economically justifiable solution as described in Section 3.4.7.3.1. Using all of the information developed, the team compared the alternatives to each other to screen out inferior plans and identify the optimal plans. Initial screening results were presented at public meetings in October 2009. Subsequent discussions with the non-federal sponsors narrowed the alternatives to various capacities and locations of diversion channels.

3.4.4 Screening #1 Results

The initial screening process and results are fully described in Appendix O, Plan Formulation and the December 2009 Alternatives Screening Document attached to Appendix O. A summary of the screening conclusions is provided in sections 3.4.5 through 3.4.7 of this report. The initial design and economic analyses of the levee and diversion channel alternatives were based on Phase 1 hydrology (without the 2009 flood event) and steady-state hydraulic modeling calibrated to the 2006 flood event. During this screening, 11 separate plans were analyzed based on five alignments and various sizes: Minnesota Long Diversion (25,000, 35,000, and 45,000 cfs), Minnesota Short Diversion (25,000, 35,000 and 45,000 cfs), North Dakota East Diversion (35,000 cfs), North Dakota West Diversion (35,000 and 45,000 cfs), and in-town levees (2-percent and 1-percent chance level of protection).

Table 5 presents the results of the initial cost-effectiveness analyses of the alternatives. Table 6 presents the expected flood stages with diversion channels of varying capacities for either the North Dakota or Minnesota alignments. Figure 13 shows the alignments of the alternatives considered in the initial screening.

Table 5 – Phase 2, Screening #1 cost-effectiveness analysis results

Fargo-Moorhead Metro Feasibility Study
Initial Screening Results, October 2009
Screened Alternatives Ranked by Net Benefits

Alternative	First Cost *	Avg Annual Net Benefits *	Residual Damages *	B/C Ratio
MN Short Diversion 25K	962	11.0	14.3	1.22
MN Short Diversion 35K	1,092	9.4	9.3	1.17
Levee 1% chance (100-year)	902	7.7	20.9	1.17
MN Long Diversion 25K	1,055	5.6	15.0	1.10
MN Short Diversion 45K	1,264	2.5	7.4	1.04
MN Long Diversion 35K	1,260	0.3	9.8	1.00
ND East Diversion 35K	1,337	-3.1	9.2	0.95
ND West Diversion 35K	1,363	-4.4	9.2	0.94
Levee 2% chance (50-year)	840	-5.3	37.1	0.88
ND West Diversion 45K	1,439	-6.7	7.6	0.91
MN Long Diversion 45K	1,459	-8.3	8.2	0.89

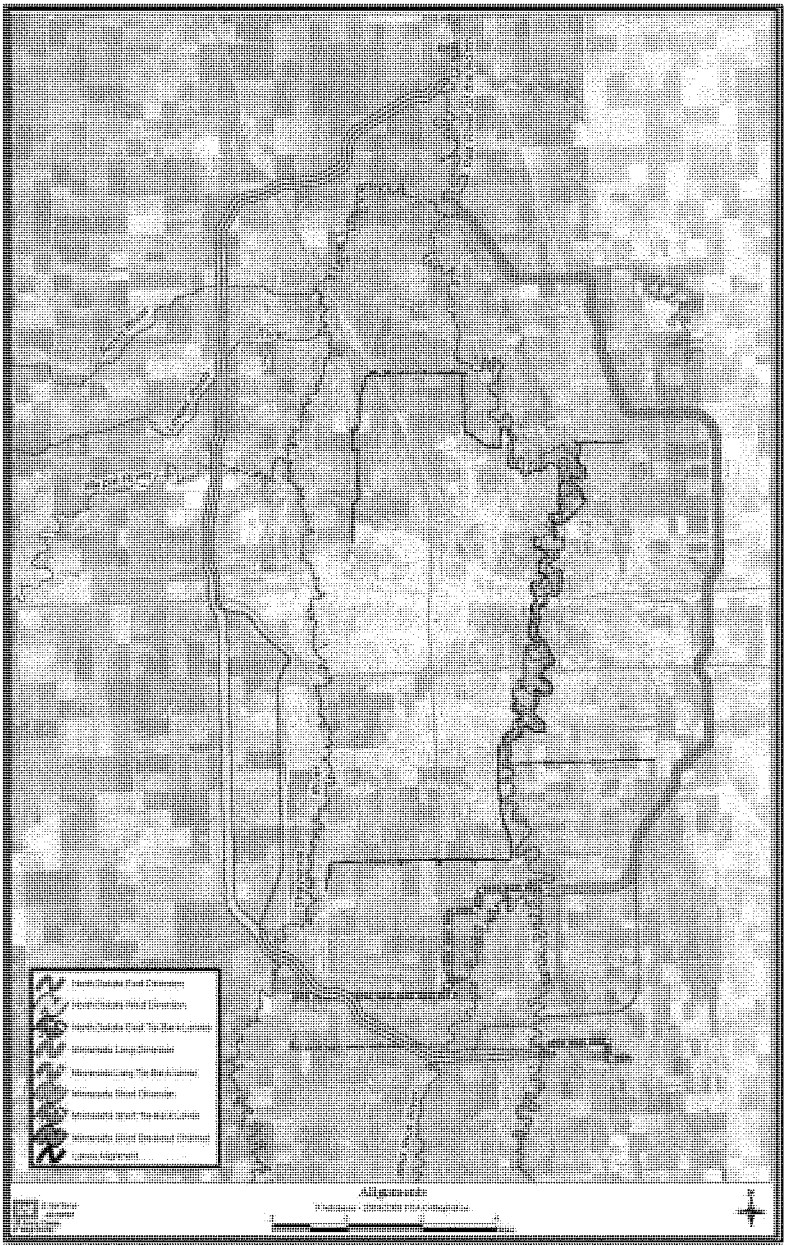
* In millions of dollars

Note: Expected average annual damages without a project were $73.7 million.

Table 6 –Phase 2, Screening #1 estimated flood stages assuming various diversion capacities

	STAGE at the FARGO GAGE		
	2% Chance (50-year)	1% Chance (100-year)	0.2% Chance (500-year)
Existing Condition	37.8	39.5	43.9
25k Diversion	29.1	30.4	39.2
35k Diversion	28.8	29.2	35.9
45k Diversion	27.1	27.2	30.4

Figure 13 – Phase 2, Screening #1 alternatives alignments



3.4.5 Preliminary Plans Eliminated from Further Consideration
The following alternatives were not recommended for further evaluation as stand-alone alternatives for this project:

- Flood Barriers
- Tunneling
- Interstate 29 Viaduct
- Dredging and Widening the River
- Increase conveyance in Oakport Coulee

Appendix O, Plan Formulation, contains a complete discussion of the screening process and the consideration given to each preliminary measure. The following paragraphs summarize the screening effort.

3.4.5.1 Flood barriers (including levees) were eliminated because they were both less effective and less cost effective than diversion plans in providing a high level of risk reduction. The top elevation of flood barrier alternatives is limited to the highest natural ground available to begin and end the levee. Within the study area, flood barriers could not be certified to contain floods larger than about a 30,000 cfs event. Such a plan would leave unacceptably high residual risk. The flood barrier plans that have been evaluated would also have caused large short-term social impacts due to the need to remove over 1,000 structures in the urban floodplain. The flood barrier plans are eliminated with knowledge of a number of uncertainties which would likely increase the overall cost, including: possible upstream impacts, the use of floodwalls versus earthen levees, geotechnical concerns, uncertainties with local pump stations, impacts to historical properties and possible mitigation.

3.4.5.2. Tunneling was eliminated from consideration due to low cost effectiveness. Tunneling would be used to divert flows under the communities; this would function similar to a diversion channel, but underground. It was estimated that at least three 30-foot diameter tunnels approximately 25 miles long would be needed to provide approximately 25,000 cubic feet per second capacity. The cost of such a plan was estimated to be $3.75 billion, which is significantly higher than the cost of a comparably-sized diversion channel.

3.4.5.3 Reconstructing the Interstate 29 (I-29) corridor to serve as an open viaduct during floods was also considered. The system would function as an interstate highway during non-flood times. It would essentially be a diversion channel with an interstate highway either on the bottom or elevated. Demolition and reconstruction of the existing Interstate highway structures and pavement would cost at least $400 million. Excavation costs would be similar to diversion channels. Real estate would be required to dispose of the excavated material. Total cost of this alternative was estimated at $1.4 billion to $4.0 billion. Operation and maintenance costs of the corridor and the roadway would be high as well. Concerns with this alternative included ice jams, access to evacuation routes during flood events, and long term maintenance of the structures. Local drainage and snow melt year-round and backwater into the channel during minor flood events would inundate the highway if it was located at the bottom of the channel.

This alternative was dropped from consideration due to low cost-effectiveness, operation and maintenance concerns and impacts to transportation.

3.4.5.4 Digging the Red River channel deeper and wider to allow for more flow to pass through the Fargo-Moorhead Metropolitan Area was considered, including work on Oakport Coulee. This alternative could also be looked at underneath existing bridges to prevent the damming effect the bridges can create. This alternative would have very limited hydraulic effectiveness and would likely have negative effects on the stability of the riverbanks throughout the length of the project. Dredging and widening the channel would have a variety of potential adverse environmental effects. Increased sedimentation, displacement of mussels, erosion issues, riparian forest habitat loss, aquatic habitat, and wildlife mortality issues would need to be addressed. This alternative would also have a large potential impact on archeological resources, which are typically located on riverbanks and would be disturbed. Because of the extreme environmental impacts, this alternative would violate many local and national policies and is not acceptable. The alternative was dropped due to its relative ineffectiveness and overall unacceptability.

3.4.6 Preliminary plans dropped as stand-alone plans but retained for possible inclusion

The following measures were retained for possible inclusion as features of the alternative plans where they could be incrementally economically justified:

- Non-Structural Measures
- Flood Storage
- Wetland and Grassland Restoration
- Bridge Replacement or Modification
- Cut-Off Channels
- Levees

3.4.6.1 Non-structural measures were eliminated as stand-alone plans because they were not found to be cost effective. Additionally non-structural measures would provide protection from property damage but evacuation would be required due to impacts on local infrastructure. This would cause large disruptions to transportation and businesses, and these impacts could last more than a month. Three levels of comprehensive, stand-alone, non-structural plans were investigated for the study area: 1-percent chance, 0.5-percent chance and 0.2-percent chance (based on Phase 1 hydrology). None of the plans were cost-effective, with total costs of $1.6 billion, $3.3 billion and $4.7 billion and benefit/cost ratios of 0.35, 0.37 and 0.31, respectively. Due to the extremely flat nature of the floodplain, it appears that it is not efficient to address flooding on an individual structure basis over the entire Fargo-Moorhead study area. Non-structural measures were retained for possible application in smaller areas not benefited by other features of the final plan where they could be economically justified. The entire non-structural analysis can be found in Appendix P.

3.4.6.2 Flood storage and wetland and grassland restoration were eliminated as stand-alone alternatives because they would be both less effective and less cost effective than diversion plans in providing a high level of risk reduction. Flood storage involves both preserving natural floodplain areas and building dams and other water retention facilities to hold water during flood events. Flood storage concepts include large dams, distributed smaller storage sites, controlled field runoff, use or modification of the constructed road network to store water (the "waffle plan"), storage ponds used for water conservation, and payment to landowners for water retention. These facilities could be located in any watershed upstream of the Fargo-Moorhead Metropolitan Area and be distributed throughout that area. Estimates of potential stage reduction that could be achieved with flood storage varied from less than 1.6 feet to 5 feet for approximately a 1-percent chance event, depending on various assumptions. The Corps' Fargo-Moorhead and Upstream Feasibility Study found that 200,000 to 400,000 acre feet of storage would need to be constructed to achieve a stage reduction of 1.6 feet at the Fargo gage for a 32,000 cfs event. If the pool was assumed to be 10 feet deep it would require 40,000 acres of land upstream of the Fargo-Moorhead area to achieve 400,000 acre feet of storage. Stage reductions during floods larger than the 1-percent chance event would be less than 1.6 feet. The study team and sponsors agreed that such a level of stage reduction would leave unacceptable residual flood risk in the study area and would not be able to meet the purpose and need of this study. The diversion plans could provide much larger and more reliable stage reductions for a similar financial investment. These measures were retained for possible application where they could be economically justified.

3.4.6.3 Bridge replacement or modification was eliminated as a stand-alone alternative because it would not be effective in substantially reducing flood risk in the study area. This concept was retained for possible application as part of an overall plan where it could be economically justified.

3.4.6.4 Cut-off channels were eliminated as a stand-alone alternative because they would not be effective in substantially reducing flood risk in the study area. This concept was retained for possible application as part of an overall plan where it could be economically justified.

3.4.6.5 Levees were retained for inclusion in diversion alternatives. Tie-back levees at the inlet of diversion alternatives are crucial for diverting flows into the diversion channel. Small in-town levees could be used to allow more flows through the existing Red River channel and could be part of an overall plan where it could be economically justified.

3.4.7 Preliminary plans retained for further evaluation

The following stand-alone alternatives were recommended for further evaluation:

- Future without Project Condition--No Action (continue emergency measures)
- Diversion Channels

3.4.7.1 The no action alternative was retained as the baseline condition to which all other alternatives are compared.

3.4.7.2 The diversion channel concept was retained for further refinement. The preliminary analysis indicated that the Minnesota Short diversion was the most cost effective of all plans considered and would be implementable and highly effective. All of the diversions studied produced lower residual damages than the levee alternatives. Since the most cost effective plan identified was the smallest capacity diversion considered, it was noted that a smaller capacity might be optimal. It was also noted that none of the North Dakota alignments provided positive net benefits, but the preliminary economic analyses omitted potential economic benefits from tributary flooding that would be uniquely addressed by a North Dakota diversion. The preliminary analyses omitted other benefit categories that could significantly increase the benefits for any diversion plan. Potential benefit categories included transportation and flood proofing cost avoidance. Any diversion could impact fish passage and riverine habitat. Further analysis was needed to optimize the capacity and alignment of the diversion concept and address potential impacts to the aquatic habitat.

3.4.7.3 The preliminary analyses produced information that supported further screening of the diversion alternatives at this screening step. The following paragraphs discuss conclusions drawn from the preliminary analyses that reduced the number of diversion plans retained for further analysis.

3.4.7.3.1 The initial diversion concept presented in May 2009 was a passive diversion channel without an operable river control structure; this concept was not economically justified with a benefit to cost ratio of approximately 0.65. All of the subsequent diversion concepts included a river control structure that dramatically improved performance with a modest increase in cost. Therefore, no diversion alternatives lacking a control structure were carried forward.

3.4.7.3.2 The Minnesota Short alignment outperformed the Minnesota Long alignment. There were no significant unique benefits or avoidance of any adverse environmental effects associated with the Minnesota Long alignment, so that alignment was dropped from consideration.

3.4.7.3.3 The North Dakota East alignment outperformed the North Dakota West alignment. There were no significant unique benefits or avoidance of any adverse environmental effects associated with the North Dakota West alignment, so the west alignment was dropped from consideration.

3.5 PHASE 2, SCREENING #2

3.5.1 Refined Array of Alternatives

An array of remaining alternatives was formulated using those management measures or plans that remained following the screening described above. Between November 2009 and February 2010 these plans were refined in order to determine the NED plan and to develop a locally preferred plan to more fully address the planning objectives. The second screening in Phase 2 incorporated a traditional hydrologic analysis based on the full period of record, including the 2009 event. Phase 2 hydrology indicated that at the Fargo gage a flow of 30,000 cfs had a 1-percent chance of exceedance, and a flow of 25,500 cfs had a 2-percent chance of exceedance. For reference, the 2009 flood had a flow of approximately 29,200 cfs at the Fargo gage. The hydraulic modeling was calibrated to the 2006 flood event. The alternatives were differentiated by 1) their location in either Minnesota or North Dakota, and 2) their capacity. Non-structural measures were considered as additional features in the areas immediately upstream of the diversions and in the areas near the downstream end of the diversions, where the diversions provided little or no benefit. The array of alternatives developed to greater detail was as follows:

- MN20K: Minnesota Short Diversion, 20,000 cubic feet per second (cfs) capacity
- MN25K: Minnesota Short Diversion, 25,000 cfs capacity
- MN30K: Minnesota Short Diversion, 30,000 cfs capacity
- MN35K: Minnesota Short Diversion, 35,000 cfs capacity
- ND30K: North Dakota East Diversion, 30,000 cfs capacity
- ND35K: North Dakota East Diversion, 35,000 cfs capacity
- The preceding plans with the addition of non-structural measures

3.5.1.1 Minnesota versus North Dakota location: There were several issues related to the location of the diversion that were pertinent to plan formulation:

- Phase 2, Screening #1 showed that the Minnesota alignment appeared to provide optimal net benefits (noting that additional analysis was needed to capture known but omitted benefits of the North Dakota plans).
- The Minnesota alignment was constrained on the east by the Buffalo Aquifer and on the west by the city of Dilworth, Minnesota.
- The Minnesota alignment crosses a railyard east of Dilworth, Minnesota
- Significantly more economic benefits accrue to properties in North Dakota regardless of channel location. That led to a public perception that Minnesota would suffer disproportionate harm if the diversion were located in Minnesota.
- North Dakota alignments cross five tributaries (Wild Rice, Sheyenne, Maple, Lower Rush, and Rush Rivers); Minnesota alignments cross none.
  - Tributary crossings introduce additional environmental impacts.
  - Tributary crossings provide flood risk reduction for flood events on the tributaries as well as the Red River.
- The North Dakota alignment benefits a greater geographic area and removes 50 more square miles from the 1-percent chance event floodplain than the Minnesota alignment.
- The sponsors and a majority of stakeholders preferred a North Dakota alignment.

3.5.1.2 The Phase 2, Screening #1 analysis completed in October 2009 indicated that the smallest capacity Minnesota plan considered (25,000 cfs) provided the largest net economic benefits. That suggested that an even smaller plan could optimize the net economic benefits. The final array of plans must include at least one plan smaller than the National Economic Development (NED) plan to show that the benefits cannot be maximized at a lower cost. To address this issue, a 20,000 cfs capacity Minnesota alternative was added to the array. Channel capacity is directly related to the project's effectiveness in reducing flood stages. The initial design data (presented in Table 6, above), indicated that a capacity of approximately 30,000-35,000 cfs would be needed to reduce the 0.2-percent chance event at the Fargo gage to a stage of 36 feet. The non-federal sponsors indicated that a project of that size would be needed to provide a tolerable level of residual risk, and they requested that these capacities be included in the array for both Minnesota and North Dakota alignments as potential locally preferred alternatives.

3.5.2 No Action

The "no action" alternative assumes that no project would be implemented by the federal government to achieve the planning objectives. The "no action" alternative is described in section 3.2.1 and in Chapter 2.

3.5.3 Minnesota Short Diversion alternatives

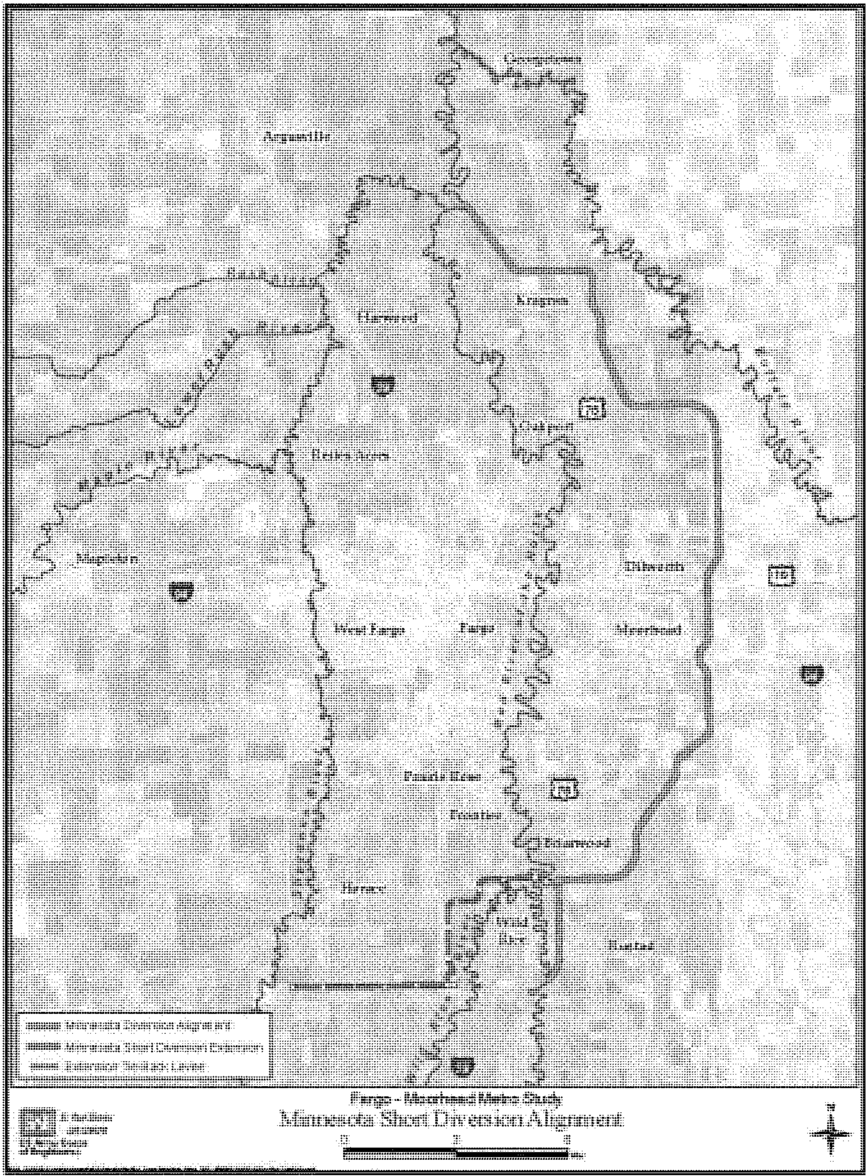
3.5.3.1 Diversion system features

The Minnesota short diversion alignment started just north of the confluence of the Red and Wild Rice Rivers and extended east and north around the cities of Moorhead and Dilworth and ultimately re-entered the Red River near the confluence of the Red and Sheyenne Rivers. The alignment of the main diversion channel was approximately 25 miles long. All four of the Minnesota plans followed the same alignment and differed only in their hydraulic capacity. The alignment and basic design features remained the same as in the earlier screening phase. The alternative consisted of the following primary features:

- Red River control structure
- Diversion inlet weir
- Main diversion channel
- Supplemental diversion channels
- Tie-back levee
- Side ditch inlet structures
- Highway bridges
- Railroad bridges

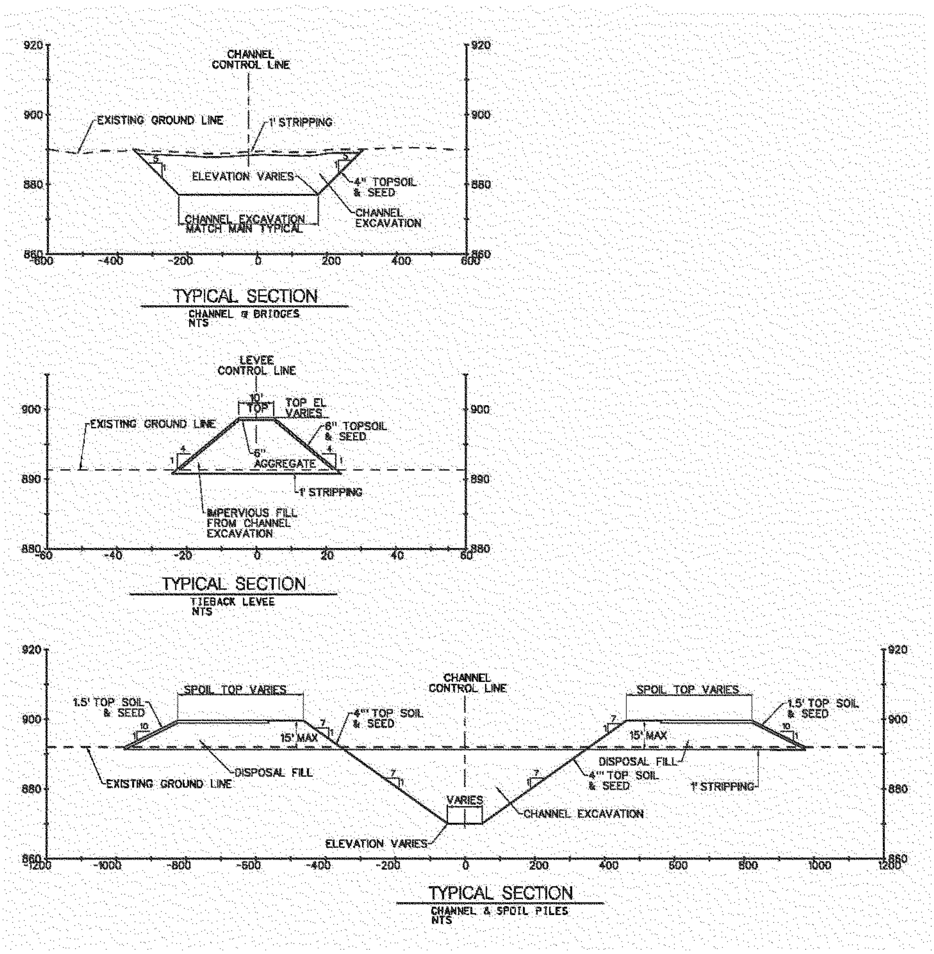
Figure 14 shows the alignment of the major features.

Figure 14 - Minnesota Short Diversion alignment



3.5.3.2 Four separate diversion capacities were initially analyzed for the Minnesota short alignment including 20,000 cfs, 25,000 cfs, 30,000 cfs and 35,000 cfs. At the end of Phase 2, two additional capacities were evaluated in an effort to bracket the NED plan: 15,000 cfs and 10,000 cfs. The channel configuration for each alternative was largely determined by constraining the maximum excavation depth to approximately 30 feet. This constraint was imposed to address geotechnical concerns based upon preliminary slope stability analyses. The channel bottom widths for the 20,000 cfs, 25,000 cfs, 30,000 cfs, and 35,000 cfs channels were 175 feet, 240 feet, 300 feet, and 360 feet respectively. Side slopes on the excavation were generally set at 1 vertical on 7 horizontal (1V on 7H) except at bridges where slopes were steeper at 1V on 5H and short reaches where other exceptions were required to achieve slope stability. Excavation quantities, being the largest portion of the construction for the diversion alternatives, were approximately 36 million, 42 million, 49 million, and 55 million cubic yards for the 20,000 cfs, 25,000 cfs, 30,000 cfs, and 35,000 cfs channels respectively. The Minnesota short alignment also included 20 highway bridges and four railroad bridges. Cross sections of the typical bridges, tie-back levees, and diversion channels can be seen in Figure 15.

Figure 15 – Typical cross section, bridges, tieback levee, and diversion channel.



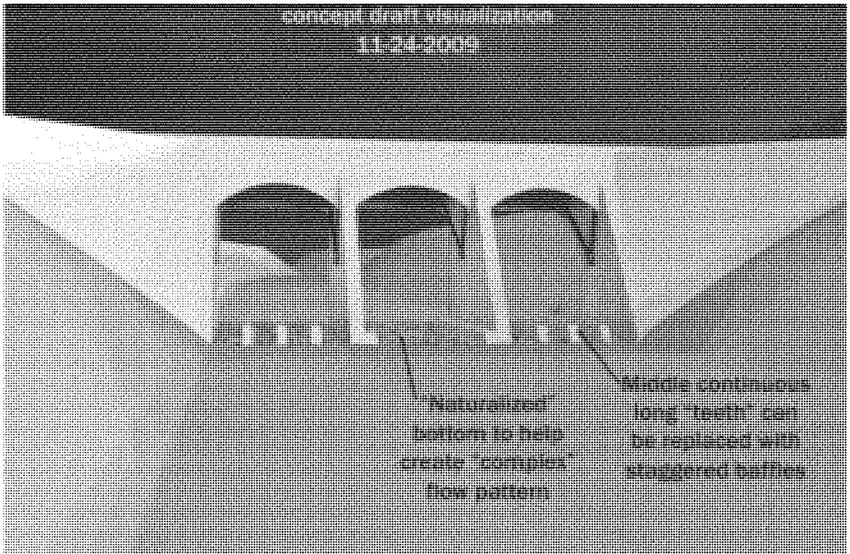
3.5.3.3 Soil excavated to construct the channel would be piled adjacent to the channel to a maximum height of 15 feet. The soil disposal piles would be as wide as necessary to contain the excavated material. The spoil slopes were 1V on 7H and 1V on 10H for the diversion side and outside slopes respectively. Portions of the soil disposal piles would be constructed to serve as levees when the water surface in the channel is higher than the natural grade. The total footprint of the MN35K plan had a maximum width of 2150 feet including areas for spoil piles. The affected acreages ranged from 4,485 acres to 6,415 acres for the MN20K and MN35K plans, respectively.

3.5.3.4 In addition to the main diversion channel, the Minnesota plans included two smaller channels upstream of the Red River control structure to prevent stage increases upstream of the project along the Red and Wild Rice Rivers. A supplementary channel paralleled the Red River upstream of the entrance to the diversion channel to allow for additional capacity to offset the breakouts to Drains 27 and 53. This secondary "Minnesota short extension channel" was approximately 3 miles long and had a 215 foot bottom width. A second, shorter channel, the Wild Rice River breakout channel, was added near the intersection of I-29 and Cass County Highway 16. The breakout channel was less than one mile long and had a 50 foot bottom width. It crossed under I-29 to convey water across I-29 that would have naturally broken out to Drain 27. These two supplemental features were also included in the previous analysis of this alignment.

3.5.3.5 The plan included a control structure on the Red River at the south end of the project. The Red River control structure allowed for the maximum benefit for a given diversion channel capacity by reducing water surface elevations immediately downstream of the structure. Additionally, the control structure allowed the water surface elevation upstream of the project to remain at a near natural elevation to prevent erosion-causing velocities in the Red River at the upstream end of the project. The flow split between the diversion channel and the Red River would be controlled by a combination of the control structure on the Red River and a weir at the entrance to the diversion channel. The diversion inlet weir crest would be set at an elevation that would allow all flows up to 9,600 cfs (between the 50-percent chance and the 20-percent chance events) to pass through Fargo-Moorhead. The weir would be constructed of sheet pile and rock.

3.5.3.6 The proposed Red River control structure would be an operable structure with three tainter gates 40 feet wide and 40 feet high. The gates would normally be fully open, and the structure would not impede flow more than a typical highway bridge up to a flow of 9,600 cfs. At that flow, the gates would be lowered to direct some of the flow into the diversion channel. The lowest four feet of each gate bay would remain open even when the gates were closed to allow flow into the natural channel under all conditions. The structure would allow small boat navigation when the gates are open. Figure 16 illustrates the conceptual control structure.

Figure 16 – Conceptual Red River control structure, looking upstream



3.5.3.7 The Red River control structure was designed with consideration for fish passage during most flow conditions. The bottom of the structure would be constructed to simulate natural roughness. The openings would be sized to maintain passable flow velocities until the gates were put into operation. After the gates were closed, smaller openings through the structure would direct some water into fish passage channels (not shown) that would continue to allow fish passage during flood events up to about the 2-percent chance event.

3.5.3.8 The plan also included a tie-back levee at the southern limits of the project. The tie-back levee would connect the Red River control structure to high ground and prevent flood water from flowing overland to the north and west into the protected area. Figure 14 shows the alignment for the tie-back levee. No tie-back levees at the north end of the project were included. The typical section for the tie-back levee had a top width of ten feet and side slopes of 1V on 4H. The tie-back levee would be constructed of impervious fill obtained from the channel excavation and covered with topsoil and turf.

3.5.3.9 A number of side ditch inlet drop structures would be included where the diversion crossed existing agricultural and highway drainage ditches. These structures would allow drainage to enter the channel and prevent water in the diversion channel from escaping to adjacent areas during high flow events.

3.5.3.10 The downstream end of the diversion channel would be protected with rock riprap where it returned to the Red River.

3.5.3.11 The primary constraints on the Minnesota alignment were the city of Dilworth, Minnesota, located immediately east of Moorhead, and the Buffalo Aquifer, located approximately 2.5 miles east of Dilworth. Two railroad switchyards were further considerations in determining the channel alignment in this area. The proposed alignment balanced these three constraints to minimize potential impacts to existing structures in Dilworth, avoid excavating into the aquifer, and minimize the number of railroad bridges and related impacts to the railyards.

3.5.3.12 A critical path analysis was completed on the Minnesota diversion channel, and it was determined that the Dilworth railyard relocation would be on the critical path. This resulted in an estimated construction period of 7.5 years for all of the Minnesota diversion alternatives, assuming funding was available as needed. The various sized plans would not have different construction schedules, because the railyard would be the controlling factor rather than the excavation of the diversion channel.

3.5.3.13 There were opportunities to incorporate wetland creation into the bottom of portions of the channel. These features could be developed at little to no cost and could provide additional wildlife habitat for the region.

3.5.4 North Dakota East Diversion

3.5.4.1 Diversion system features

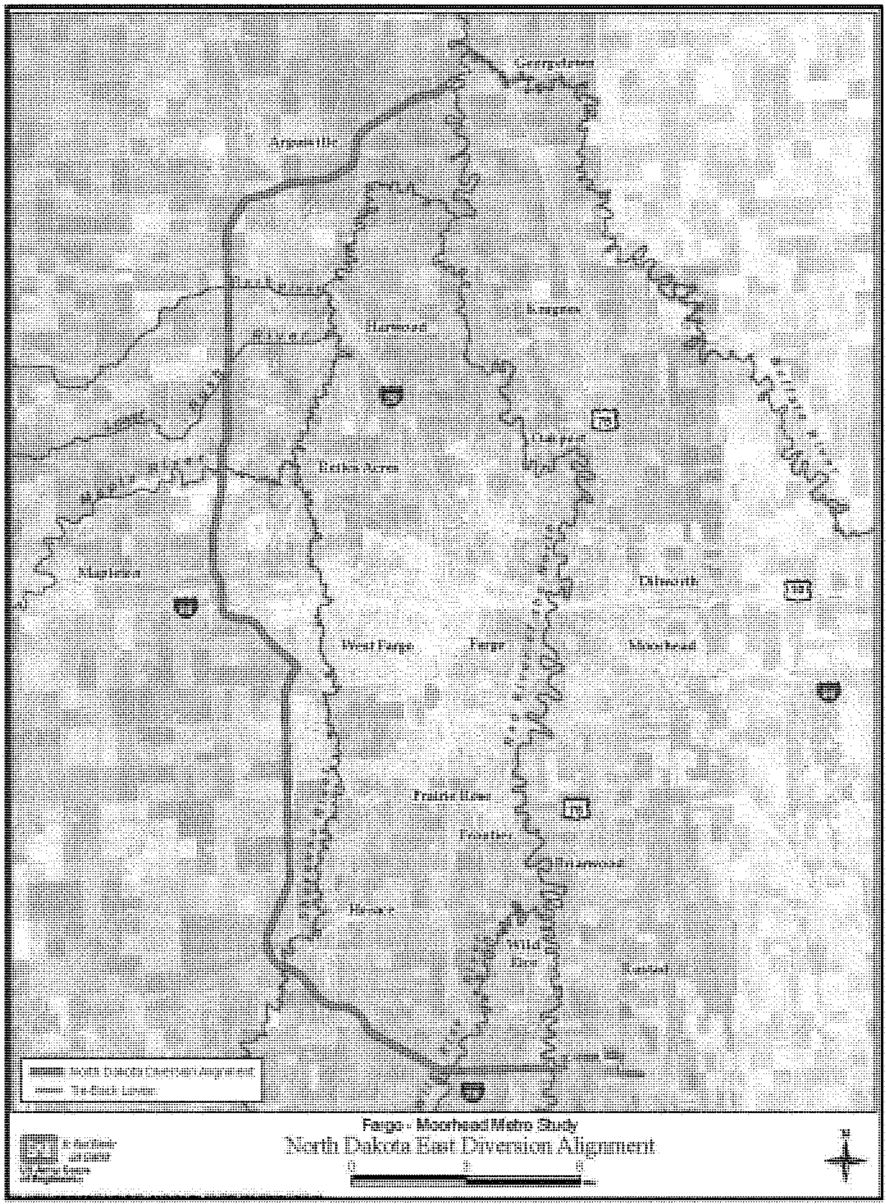
The North Dakota east diversion alignment started approximately four miles south of the confluence of the Red and Wild Rice Rivers and extended west and north around the cities of Horace, Fargo, West Fargo, and Harwood and ultimately re-entered the Red River north of the confluence of the Red and Sheyenne Rivers near the city of Georgetown, MN. The alignment was approximately 36 miles long and incorporated the existing Horace to West Fargo Sheyenne River diversion channel. The basic alignment remained the same as in the earlier screening phase, but significant changes were made to optimize the channel cross section, reduce cost, and improve the efficiency of the hydraulic structures. The plans consisted of the following primary features:

- Red River control structure
- Connecting channel (Red River to Wild Rice River)
- Wild Rice River control structure
- Diversion inlet weir (at Wild Rice River)
- Main diversion channel
- Sheyenne River crossing structure
- Maple River crossing structure
- Lower Rush River diversion structure
- Rush River diversion structure
- Tie-back levee
- Side ditch inlet structures
- Highway bridges

- Railroad bridges

Figure 17 shows the alignment of the major features.

Figure 17 - North Dakota East diversion alignment



The North Dakota east alignment was analyzed at 30,000 cfs and 35,000 cfs capacities based on the non- federal sponsors' request for them to be considered as a locally preferred plan. The channel configuration for each plan was largely determined based on the minimum excavation quantity for a given capacity rather than by the maximum recommended excavation depth as was used for the Minnesota alignment. The maximum depth for the North Dakota plans was 32 feet, as opposed to 30 feet for the Minnesota plans. The channel bottom width between the Red and Wild Rice Rivers was 300 feet for both capacities. For the ND30K plan, the channel bottom width was 80 feet between the Wild Rice River and the downstream end of the diversion. For the ND35K plan, the channel bottom width was 100 feet between the Wild Rice and Sheyenne Rivers and 125 feet between the Sheyenne River and the downstream end of the diversion. Side slopes on the excavation were set at 1V on 7H except at bridges where slopes were steeper at 1V on 5H. Both North Dakota plans included 18 highway bridges and four railroad bridges. Cross sections of the typical bridges, tie-back levees, and diversion channels can be seen in Figure 15.

Soil excavated to construct the channel would be piled adjacent to the channel to a maximum height of 15 feet. The soil disposal piles would be as wide as necessary to contain the excavated material. The spoil slopes were 1V on 7H and 1V on 10H for the diversion side and outside slopes respectively. Portions of the soil disposal piles would be constructed to serve as levees when the water surface in the channel is higher than the natural grade. The total footprint of the ND35K plan had a maximum width of 2150 feet including areas for spoil piles. The affected acreage was 6,105 acres and 6,560 acres for the ND30K and ND35K plans, respectively.

Because this alignment began south of the confluence of the Red and Wild Rice Rivers, a connecting channel was included between the Red and Wild Rice Rivers. The connecting channel would convey flow from the Red River to the diversion channel inlet on the west side of the Wild Rice River.

A combination of control structures on the Red and Wild Rice Rivers at the south end of the project, along with weirs at the west end of the connecting channel and at the entrance to the diversion channel near the Wild Rice River, would control the flow split between the Red and Wild Rice River channels and the diversion channel. The diversion inlet weir crest would be the controlling weir and would be set to allow flows up to 9,600 cfs to pass through Fargo-Moorhead. The 9,600 cfs flows were intended to maintain existing geomorphologic processes and existing habitat conditions in the natural channels.

The proposed Red River control structure would be an operable structure similar to the one proposed for the Minnesota diversion plans, except the three tainter gates would be 40 feet wide and 30 feet high. (See Figure 16 and discussion in sections 3.5.3.6 and 3.5.3.7)

The proposed Wild Rice River control structure, similar to the Red River control structure, would be an operable structure with two tainter gates 30 feet wide and 20 feet high. The gates would normally be fully open, and the structure would not impede flow more than a typical highway bridge. The gates would be operated to allow flows up to 9,600 cfs to pass through Fargo-Moorhead. At that flow, the gates would be lowered to direct some of the flow into the diversion channel. The lowest two feet of each gate bay would remain open even when the gates were closed to allow flow into the natural channel under all conditions. The structure would allow small boat navigation when the gates were open. The Wild Rice River control structure would be conceptually the same as the Red River control structure illustrated in Figure 16, except that the Wild Rice structure would have only two gates. This structure also incorporates features for fish passage as generally described in section 3.5.3.7.

The tie-back levee associated with this alternative would connect the Red River control structure to high ground approximately 2.5 miles to the east and prevent flood water from flowing over land to the north and east into the protected area. No tie-back levees at the north end of the project were included. The typical section for the tie-back levee had a top width of ten feet and side slopes of 1V on 4H. The tie-back levee would be constructed of impervious fill obtained from the channel excavation and covered with topsoil and turf.

The ND30K and ND35K plans crossed the Sheyenne, Maple, Lower Rush, and Rush Rivers. Systems of hydraulic structures were necessary at the points where the diversion channel crossed these rivers. The tributary crossing structure systems would limit the amount of water that could pass over the diversion channel with the rest of the water being diverted into the diversion channel. This resulted in additional flood damage reduction benefits adjacent to the tributaries downstream of the intersection. Careful consideration was given to the crossing structure systems to minimize impacts to fish passage on the tributary streams. This is described in Chapter 5 of this report, Environmental Consequences.

The Rush and Lower Rush Rivers, which currently consist of constructed trapezoidal channels, would flow into the diversion channel, resulting in abandonment of the downstream portion of these rivers. The structures at the junction of the Rush and Lower Rush Rivers and the diversion channel were also designed to allow fish passage from the diversion channel into the upstream tributary channels during most flow conditions. From the Lower Rush River to the Red River the bottom of the diversion channel would be designed to provide wildlife habitat. This would be accomplished by including a meandering pilot channel and using native species. There would also be opportunities to incorporate wetland creation into the bottom of other portions of the channel. These features could be developed at little to no cost and could provide additional wildlife habitat for the region.

The hydraulic structure systems proposed on the Sheyenne and Maple Rivers would allow a minimum of a 50-percent chance event flow to continue down the rivers while diverting excess water during flood events to the diversion channel. The 50-percent chance event flows are intended to maintain existing geomorphologic processes and existing habitat conditions in the natural channels. The Sheyenne and Maple River structures would remain biologically connected and maintain fish passage to those rivers nearly all of the time, except possibly for events larger than the 1-percent chance event. The two crossing structure systems were similar in concept; each included a drop structure to prevent headcutting on the tributary, a spillway and channel to control diversion of tributary flows, and a hydraulic structure to pass a limited flow over the diversion channel to maintain the desired flow in the tributary beyond the diversion channel. The primary difference between the Sheyenne system and the Maple system was the presence of gated openings on the Maple system's hydraulic structure. The gates were necessary because the structure was designed to allow flows in the diversion channel to overtop the Maple River crossing structure. The gates would operate to prevent excessive flows from passing into the Maple River during extreme flood events. Figure 18 through Figure 24 illustrate the conceptual structures on the Sheyenne and Maple Rivers.

Figure 18 – Flow in Sheyenne River, no flow over spillway or in diversion

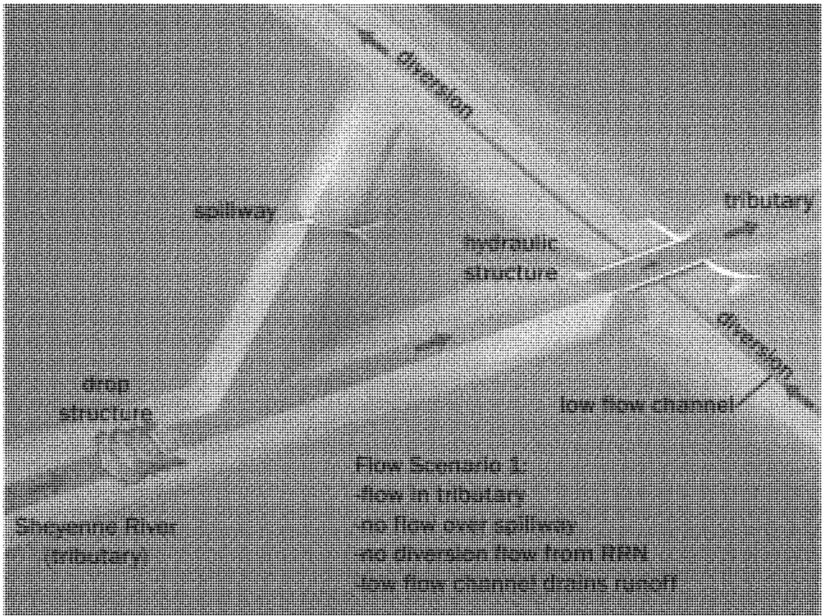


Figure 19 – Flow in Sheyenne, flow over spillway and flow in diversion

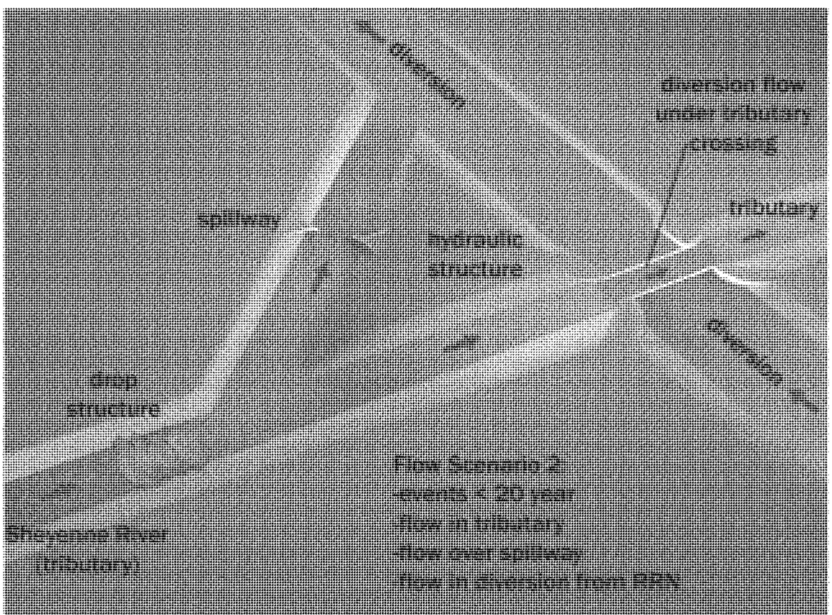


Figure 20 - Flow in Sheyenne River, no flow over spillway or in diversion looking at structure

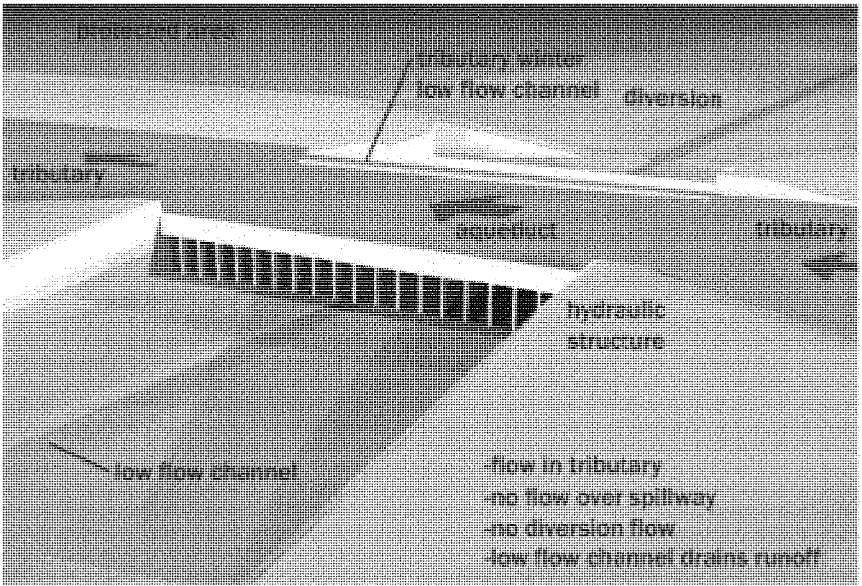


Figure 21 - Flow in Maple River, no flow over spillway or in diversion.

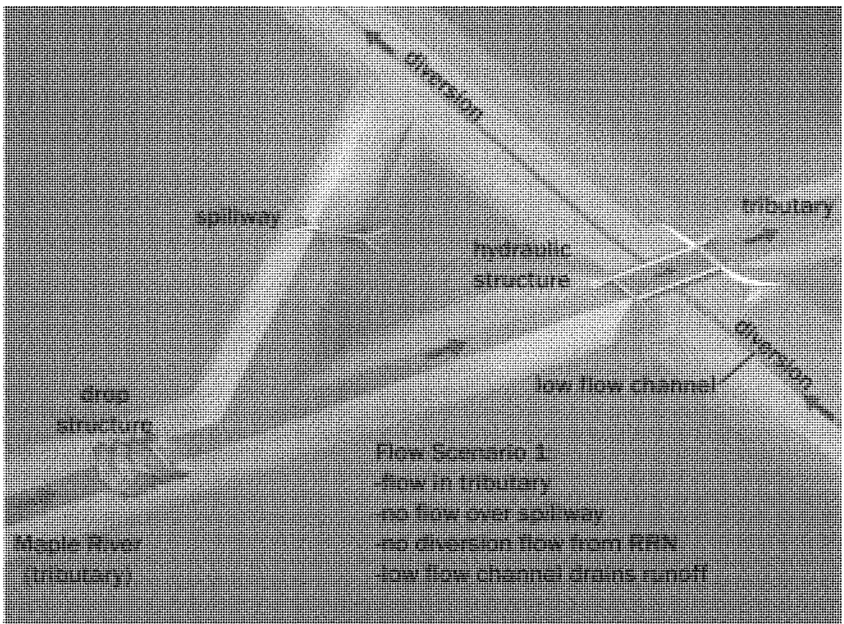


Figure 22 – Flow in Maple River, flow over spillway, and flow in diversion

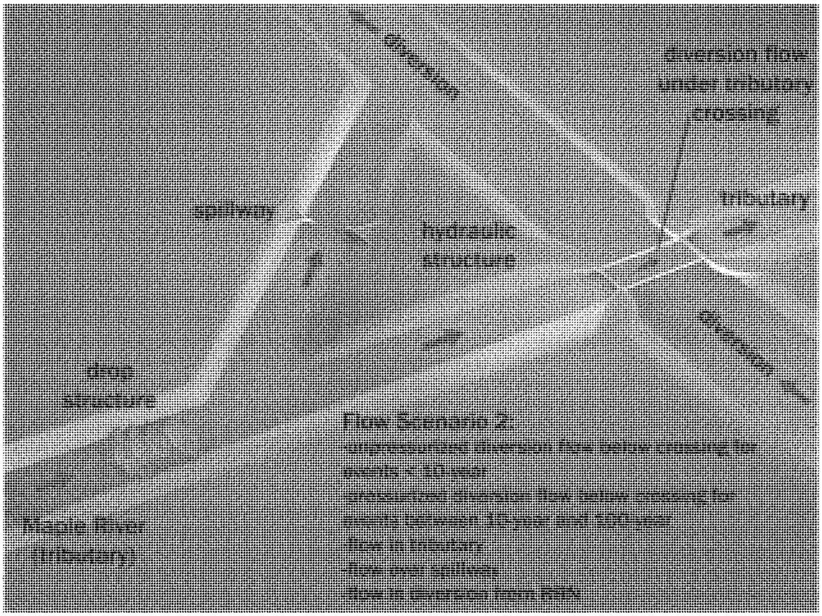


Figure 23 – Maple River and Diversion flows, Diversion overtops Maple River.

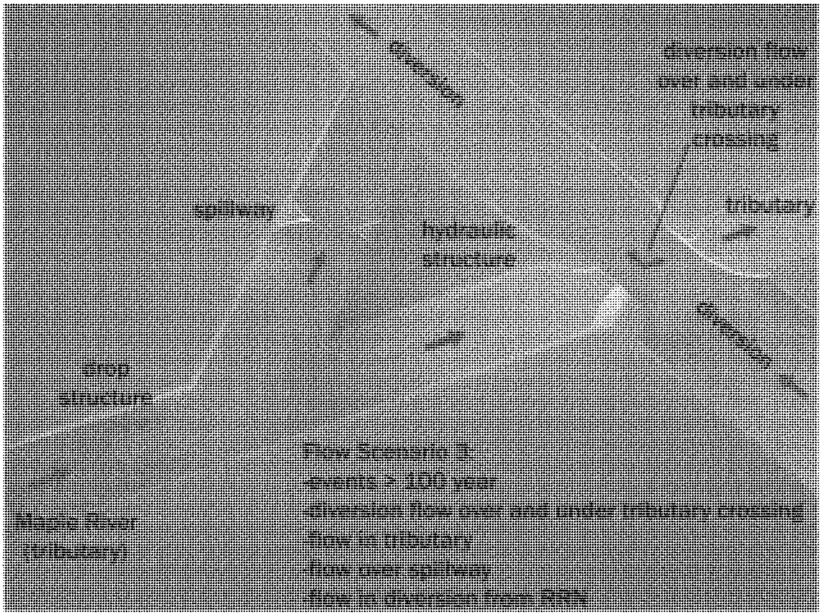
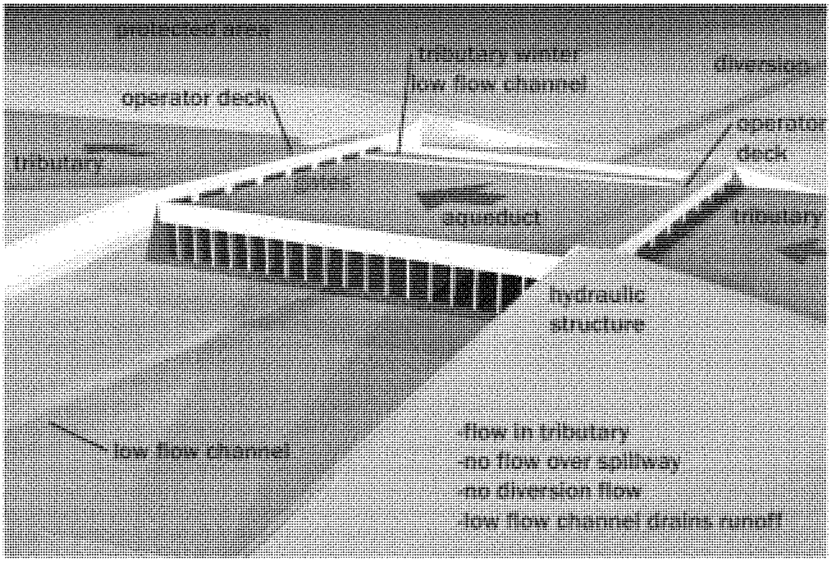


Figure 24 – Flow in Maple River, no flow over spillway or in diversion, looking upstream at structure.



A number of side ditch inlet drop structures would be included where the diversion crosses existing agricultural and highway drainage ditches. These structures would allow drainage to enter the channel and prevent water in the diversion channel from escaping to adjacent areas during high flow events.

The downstream end of the diversion channel would be protected with rock riprap where it returned to the Red River.

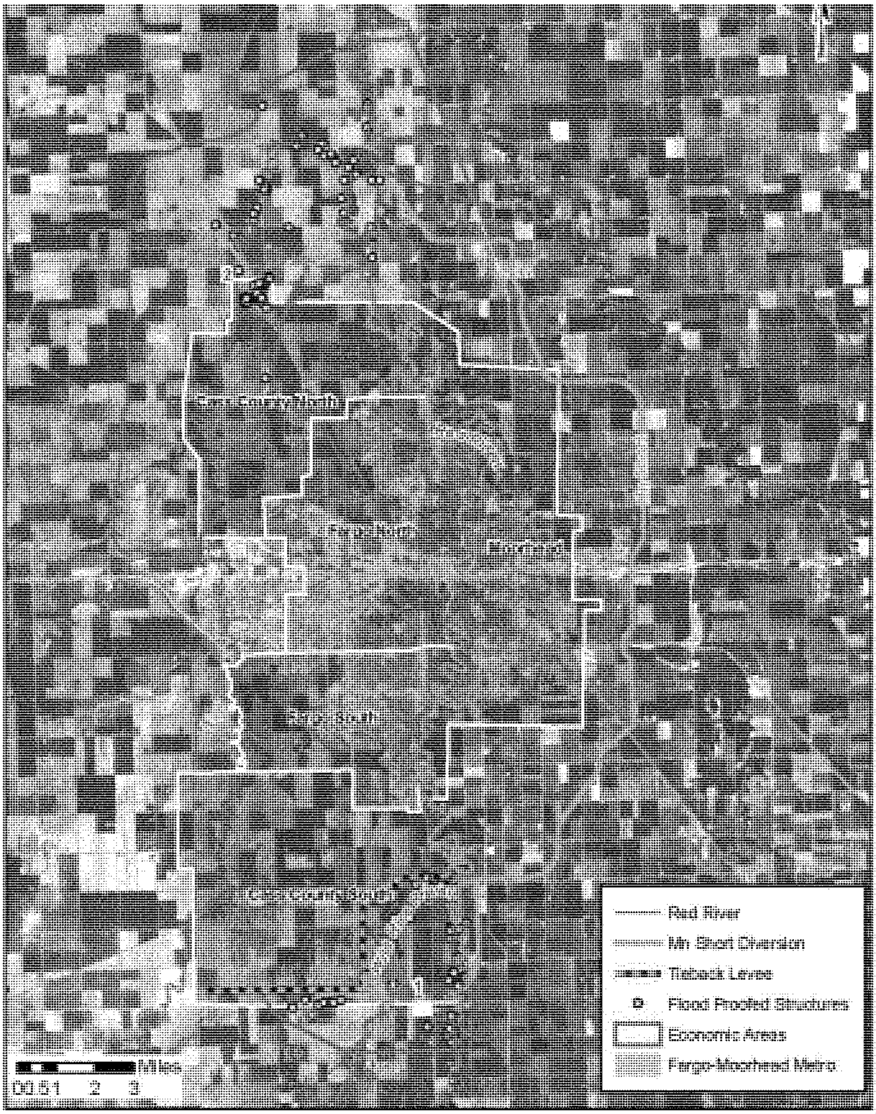
3.5.4.2 A critical path analysis was completed on the North Dakota diversion channel, and it was determined that the Maple River structure would be on the critical path. This resulted in an estimated construction period of 8.5 years for all of the North Dakota diversion alternatives, assuming funding was available as needed. The various sized plans would not have different construction schedules, because the Maple River structure would be the controlling factor rather than the excavation of the diversion channel.

3.5.5 Non-structural measures

Non-structural measures were analyzed as an additional incremental feature to be included in any of the diversion plans. Two areas were evaluated for residual flood impacts that could be addressed with non-structural measures: Economic Area 1 upstream and Economic Area 2 downstream. Economic Area 1 was the area upstream of the proposed Minnesota diversion channel inlet to approximately four miles south of the Wild Rice River confluence with the Red

River. Economic Area 2 was the area along the downstream reach of the Sheyenne River near the proposed diversion channel outlets. The areas analyzed are shown on Figure 25.

Figure 25 - Location of potential non-structural measures



Economic Area 1 included 48 residential structures. Potential non-structural measures applicable in this area were fee acquisitions and elevation of structures. This area was only considered in conjunction with the Minnesota plans, because the area is located downstream of the North Dakota diversion inlet, meaning it would be within the area benefited by the diversion and non-structural measures would not be necessary. It was determined that non-structural measures for Economic Area 1 were not justified for the Minnesota diversion alignments and had a benefit to cost ratio of 0.45 with net benefits of negative ($314,313).

The non-structural mitigation measures proposed for Economic Area 2 consisted of fee acquisitions, elevation of structures and construction of flood walls. For the MN20K plan there were 57 residential structures, one commercial structure and one critical facility (ID 400802 public school) included. For the larger Minnesota plans there are 51 residential structures and one critical facility (ID 400802 public school) included. For the ND30K and ND35K plans, there were 29 residential structures included.

Non-structural measures were incrementally justified for Economic Area 2 in conjunction with all Minnesota alternatives. The non-structural measures had benefit to cost ratios of 1.04 for the MN20K plan and 1.14 for the MN25K, MN30K and MN35K plans. The non-structural features would add average annual net benefits of $17,156 for MN20K and $49,903 for the other three Minnesota plans (see Appendix P). Therefore, with the selection of any Minnesota diversion alternative the non-structural measures in Economic Area 2 would be added as a justified increment to that plan and would become part of the NED plan.

Non-structural measures were not economically justified for either North Dakota alternative. With the North Dakota diversions in place, additional non-structural measures had a benefit to cost ratio of 0.64 and net benefits of negative ($73,354) (see Appendix P).

Additional analyses of non-structural measures were conducted in Phase 4 of the study and are included in Appendix P. The Red River floodplain area from the outlet of the selected plan (see Section 3.13) downstream to Thompson, North Dakota, was evaluated to see if non-structural measures could be justified for the without project condition. It was found that nonstructural mitigation in the form of elevation, dry flood proofing, wet flood proofing, and through berms, could provide economically feasible flood risk reduction to more than 35 percent of the approximately 3,800 structures investigated. Although this analysis was not completed at a level of detail sufficient to support a project recommendation as part of the Fargo-Moorhead project, it shows that non-structural measures may be viable throughout the Red River Basin and should be considered for implementation in support of other ongoing efforts to reduce flood damages along the Red River of the North.

3.5.6 Incremental measures eliminated from further consideration

Following the development of the diversion alternatives, additional consideration was given to flood storage, wetland and grassland restoration, bridge replacement or modification and the use of cut-off channels. It was determined that these measures would not provide any additional economically justified benefits. This is due to the fact that the diversion alternatives provided a very high level of flood risk reduction, and they captured a large portion of the benefits that could be captured by a project.

The concept of using a shorter diversion to intercept only the Maple, Rush and Lower Rush rivers northwest of Fargo was considered as a potential additional feature of a Minnesota diversion plan. A preliminary analysis showed that the northwest diversion was not economically justified, so the concept was not carried forward.

3.5.7 Phase 2, Screening #2 Results

The results from the second Phase 2 screening are presented in Table 7.

Table 7 – Phase 2, Screening #2 cost-effectiveness analysis results

Screened Alternatives Ranked by Net Benefits with Cost and Schedule Risk Assessment

Alternative	Cost [1]	Avg Annual Net Benefits [1]	Residual Damages [1]	B/C Ratio
MN Short Diversion 10K[2]	$730	$1.3	$40.3	1.03
MN Short Diversion 15K[2]	$800	$11.4	$31.0	1.28
MN Short Diversion 20K	$871	$16.2	$22.7	1.41
MN Short Diversion 25K	$980	$15.5	$18.1	1.36
MN Short Diversion 30K	$1,050	$15.1	$14.8	1.33
MN Short Diversion 35K	$1,143	$12.2	$13.3	1.26
ND East Diversion 30K	$1,231	$13.3	$11.4	1.26
ND East Diversion 35K	$1,295	$11.7	$9.7	1.22

1. In millions of dollars
2. Linear Cost Extrapolations used.
Expected average annual damages without a proejct were $77.1 million.

3.5.8 Phase 2, Screening #2 Conclusions

The key findings of the second screening were:

- The Minnesota 20K plan was the apparent NED plan.
- The difference in net benefits between the Minnesota plans was relatively small, so minor changes to costs or benefits could affect identification of the NED plan.
- The North Dakota plans had positive net economic benefits, so they were economically viable as potential locally preferred plans.

3.5.9 Hydraulic and Hydrologic assumptions

Throughout the second part of Phase 2, work continued to update the hydraulic models and hydrologic data to reflect the 2009 flood event. At the completion of Phase 2, it was determined that a non-traditional hydrologic method (see Appendix A, Hydrology) would most accurately represent the expected future flow conditions during the period of analysis. In addition, the hydraulic model was re-calibrated to the 2009 event. Both changes were expected to increase estimated flood stages for any given frequency of event and potentially affect the economic analyses.

3.5.10 Selection of alternatives for further analysis

The results of the second screening were presented to the public in February 2010 and discussed with the non-federal sponsors and stakeholders at several subsequent meetings. On March 29, 2010, the cities of Fargo and Moorhead, Cass County, North Dakota and Clay County Minnesota jointly requested that the ND35K plan be pursued as a locally preferred plan (LPP). Because of the relatively small magnitude of the differences in net benefits between the Minnesota plans, and the potential impacts of the revised hydrology and hydraulic models, it was necessary to retain the MN20K, MN25K, MN30K and MN35K plans as possible NED plans to be considered in the final array in Phase 3.

3.6 FEASIBILITY PHASE 3

3.6.1 General

Phase 3 began in March 2010. Primary activities were to refine the plans and identify which of the Minnesota plans would maximize net economic benefits. These refinements included additional analysis of the impacts to the railroads and to the cross sections on the diversion channels. This analysis used the hydrologic assumptions recommended by the EOE panel and the hydraulic model which was calibrated to the 2009 event, which increased estimated flood stages for the larger flood events. The analysis was completed on the MN20, 25, 30, 35, 40 and 45K alternatives and the ND35K alternative. The ND30K alternative was dropped from further consideration when the non-federal sponsors identified the ND35K as the Locally Preferred Plan as indicated in section 3.5.10.

3.6.2 Revised Cross Section for North Dakota Diversion

The cross section of the North Dakota diversion as described in section 3.5.4.1 was modified to account for weak soils that were identified as part of the soil investigations. This resulted in the depth of the channel being raised three feet, to a maximum depth of approximately 29 feet. The channel bottom widths remained unchanged. Side slopes on the excavation were modified to be 1V on 10H up to a 10 foot high 50 foot wide bench then 1V on 7H to the top of the channel.

Soil excavated to construct the channel would be piled and set back 50 feet from the top of the diversion channel to a maximum height of 15 feet. The soil disposal piles would be as wide as necessary to contain the excavated material. The spoil slopes were 1V on 7H and 1V on 10H for the diversion side and outside slopes, respectively. Portions of the soil disposal piles would be constructed to serve as levees when the water surface in the channel is higher than the natural grade. The total footprint of the ND35K plan would have a maximum width of approximately 2450 feet including areas for spoil piles.

3.6.3 Phase 3 Economic Analysis Results

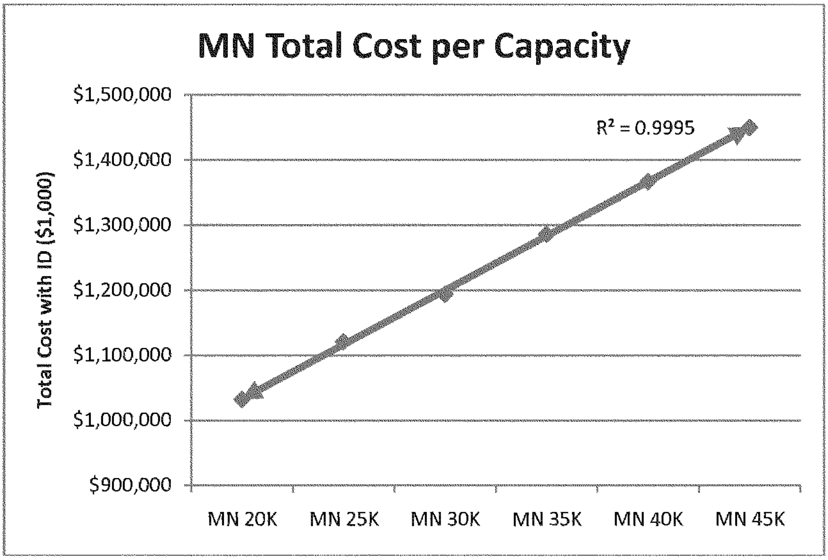
3.6.3.1 The Phase 3 final array of alternatives was analyzed in May 2010 to identify the NED plan. The initial Phase 3 work showed that the MN35K plan, the largest plan analyzed in detail, maximized net economic benefits. As a result, it was necessary to consider larger alternatives to identify the NED plan. Hydraulic models were developed for the MN40K and MN45K alternatives to fully define the with-project flood stages and economic benefits for those alternatives. Table 8 shows the estimated peak stage at the Fargo gage.

Table 8 – Phase 3 estimated flood stages assuming various diversion capacities.

	Stage at Fargo Gage (ft)	
	1% Chance (100- year)	0.2% Chance (500- year)
Existing Condition (Stage)	42.4	46.7
Existing Condition (CFS)	34,700	61,700
Work Group Goal	30	36
20K Diversion Channels	36.9	43.7
25K Diversion Channels	34.8	42.4
30K Diversion Channels	33.6	41.9
35K ND Diversion Channel	30.6	40.0
35K MN Diversion Channel	31.9	39.6
40K Diversion Channels	31.9	37.6
45K Diversion Channels	31.9	35.3

3.6.3.2 Costs for the MN40K and MN45K plans were estimated based upon linear extrapolation from the detailed estimates of the smaller Minnesota alternatives. Figure 26 illustrates the linear nature of the cost curve for these alternatives and supports the methodology used.

Figure 26 - Linear Extrapolation of Costs for the MN40K and MN45K Alternatives



3.6.3.3 The Phase 3 analyses determined that the NED plan was the MN40K plan, with maximum average annual net benefits of $105.6 million. The results of the Phase 3 cost-effectiveness analysis are presented in Table 9.

Table 9 – Phase 3 cost-effectiveness analysis results

Screened Alternatives Ranked by Net Benefits with Cost and Schedule Risk Assessment

Alternative	Cost [1]	Avg Annual Net Benefits [1]	Avg Annual Benefits [1]	Residual Damages [1]	B/C Ratio
MN Short Diversion 20K	$1,032	$87.0	$140.0	$55.9	2.64
MN Short Diversion 25K	$1,121	$98.8	$156.4	$39.5	2.71
MN Short Diversion 30K	$1,194	$101.7	$163.1	$32.8	2.66
MN Short Diversion 35K	$1,286	$104.9	$171.0	$24.9	2.59
MN Short Diversion 40K [2]	$1,367	$105.6	$175.9	$20.0	2.50
MN Short Diversion 45K [2]	$1,450	$104.9	$179.5	$16.4	2.41
ND East Diversion 35K	$1,462	$95.4	$171.1	$24.8	2.26

1. In millions of dollars with interest during construction and discounting included
2. Estimate based on linear extrapolation
Expected average annual damages without a project were $195.9 million.

3.6.3.4 It is interesting to note that the NED plan does not produce the highest benefit-cost ratio. The definition of the NED plan is based upon maximizing average annual net benefits rather than maximizing benefit-cost ratio.

3.6.4 Reconsideration of the ND35K plan as the Locally Preferred Plan (LPP)

On April 28, 2010, the Assistant Secretary of the Army for Civil Works authorized the Corps to recommend the ND35K plan as the non-federal sponsors' LPP, as described in section 3.9.3.2 of this report. After considering the Phase 3 results, the non-federal sponsors reaffirmed their preference for the ND35K plan. It was noted that the revised hydrology and hydraulics affected the nominal performance of the ND35K plan, and it would no longer produce the locally desired stage of 36.0 on the Fargo gage for a 0.2-percent chance event.

3.6.5 Screening of the MN40K (NED) plan and the MN45K plan

Selection of the ND35K plan as the LPP made further consideration of the NED plan (MN40K) unnecessary. Federal cost sharing for the ND35K plan could not be based on the NED plan, because the ND35K plan produced fewer total average annual benefits than the NED plan, at \$171.1 million and \$175.9 million, respectively. Instead, federal cost sharing would be based upon a smaller Minnesota alternative that produced a comparable level of benefits to the ND35K plan. Table 9 shows that the MN35K plan and the ND35K plan produced comparable benefits, at \$171.0 million and \$171.1 million respectively. Since the MN35K plan would serve as the basis for federal cost sharing, there was no need to fully develop the MN40K (NED) plan. For purposes of the feasibility study, it was only necessary to demonstrate that the NED plan was larger than the MN35K plan. For that reason, the MN40K (NED) plan and the MN45K plan were dismissed from further consideration, and the MN35K plan would be refined for comparison with the ND35K plan for cost-sharing purposes. The MN35K plan was therefore identified as the Federally Comparable Plan (FCP).

3.6.6 Validation of earlier screening steps

The Phase 3 economic analyses completed in May 2010 validated the October 2009 and January 2010 screening steps. Decisions made at earlier steps were based on the best available hydraulic and hydrologic data available at that time. Subsequent information indicated that the earlier assumptions underestimated both the flow frequency and expected flood stages. As a result, all of the plans previously considered and screened out during the earlier screening steps, including levee and storage alternatives, would provide more benefits but would leave higher residual flood risk than was identified at the time. The best available data at the conclusion of Phase 3 confirmed that the diversion channel concept was the only concept that could provide a high level of flood risk reduction in the study area.

3.6.7 Downstream and upstream impacts

At the end of Phase 3, there were two primary issues related to downstream impacts of the diversion plans. The first issue was the potential effect of induced economic damages on identification of the NED plan. The second issue was the inability to determine the full extent of the impacts and identify the location where impacts dissipated to a negligible amount, which made it necessary to modify the LPP. These issues are discussed below.

3.6.7.1 No effects on selection of NED plan: At the end of Phase 3, the analysis of downstream impacts of the diversions was incomplete. However, it was determined that downstream impacts would not affect the selection of the NED plan. All of the Minnesota diversions would have similar performance up to their design capacity; for any given flood, each channel would divert the same amount of water up to its full capacity. All of the diversions would convey similar flows for more frequent events, and differences in downstream impact would primarily occur in the larger less frequent events. Economic damages due to downstream impacts would not vary significantly with the size of channel, because the infrequent events would add relatively little to the annualized damages. Since downstream impacts would be relatively similar for all of the alternatives, downstream impacts would not affect the identification of the NED plan, and it was not necessary to quantify the impacts from the smaller plans in order to identify the NED plan. During Phase 3, downstream impacts were only modeled for the MN35K and ND35K plans.

3.6.7.2 Effects on the LPP: Throughout Phases 1-3 of the study, the diversion alternatives were designed to have only downstream stage increases and it was expected that any downstream stage increases would be relatively small and dissipate relatively quickly. Prior to release of the Draft Report and Environmental Impact Statement in May 2010, the unsteady HEC-RAS models showed downstream impacts to Halstad, MN. Following the release of the Draft Report the models were extended downstream to Thompson, ND (101 river miles downstream of the diversion outlet). The models showed impacts at Thompson of nearly 16 inches for a 1-percent chance event with the ND35K diversion. Based on these results, it was determined that additional modeling was required to identify a point downstream with minimal to no impacts and that consideration would need to be given to other options such as upstream staging.

3.6.8 Phase 3 Conclusions

3.6.8.1 NED Plan: Based on the Phase 3 analyses, the MN40K plan was the plan that reasonably maximized the net national economic development benefits and was therefore the NED plan. No further analysis was needed to define the NED plan.

3.6.8.2 Locally Preferred Plan (LPP): The ND35K plan was identified as the LPP and the tentatively selected plan in the May 2010 Draft Report and Environmental Impact Statement. However, due to the extent of the downstream impacts, it was necessary to consider modifications to the ND35K plan, including options that would cause upstream impacts.

3.6.8.3 Federally Comparable Plan (FCP): The LPP provided fewer total average annual benefits than the NED plan. Therefore, as described in section 3.6.5, it was necessary to develop a plan smaller than the NED plan that could be compared to the LPP for cost-sharing purposes. Table 9 shows that the MN35K plan would provide similar total average annual benefits and residual damages compared to the LPP. Therefore, the federal investment in the LPP should be capped at the investment that would have been made for the comparable MN35K plan.

3.7 FEASIBILITY PHASE 4

Phase 4 focused on extending and refining the unsteady HEC-RAS hydraulic models and using the models to assess several strategies to minimize project impacts. The strategies that were considered included shifting the diversion further north (to near the MN35K plan's inlet), staging water upstream on the Red and Wild Rice rivers, passing additional water through the protected area in the Maple River's natural channel, and using off-channel storage areas along the diversion channel. The study team assessed several different channel sizes and slopes in combination with various amounts of upstream staging and temporary storage within the protected area to achieve a definable impacted area. The control structures in the design were operated as necessary to achieve the desired hydraulic conditions in the Red River channel through Fargo-Moorhead.

This ultimately resulted in 3 plans being considered: the FCP as defined in Phase 3 (see section 3.12 below), the ND35K as defined in Phase 3 (the LPP in the May 2010 Draft Environmental Impact Statement; see section 3.11 below), and the redefined LPP, which is the North Dakota diversion with upstream storage and staging (see section 3.13 below).

3.7.1 NED Analysis

The steps leading to the identification of the NED plan were revisited to determine if the NED plan was likely to change. Additional measures were developed as part of Phase 4, and additional hydraulic modeling was conducted. Therefore, it was necessary to review the NED analysis. The Phase 4 NED analysis focused on logic checking based on the new information, and showed that the MN40K as defined in Phase 3 was likely still the NED plan. This analysis is presented in detail in section 8.4 of Appendix O.

3.7.2 Description of the LPP (North Dakota diversion with upstream staging and storage)

The LPP diversion alignment starts approximately four miles south of the confluence of the Red and Wild Rice Rivers and extends west and north around the cities of Horace, Fargo, West Fargo, and Harwood and ultimately re-enters the Red River north of the confluence of the Red and Sheyenne Rivers near the city of Georgetown, MN. The alignment is approximately 36 miles long and incorporates the existing Horace to West Fargo Sheyenne River diversion channel. The basic North Dakota alignment is the same for the ND35K plan and the LPP; the alignment remained the same as in the earlier screening phase, except where it was adjusted northwest of Harwood, ND to avoid Drain 13. Some significant design changes were made for the LPP including the addition of staging and storage, as well as additional changes to optimize the channel cross section. The LPP includes 19 highway bridges and 4 railroad bridges that cross the diversion channel. Interstate Highway 29, U.S. Highway 75 and a BNSF railroad line would be raised within the staging area to maintain transportation during flood events.

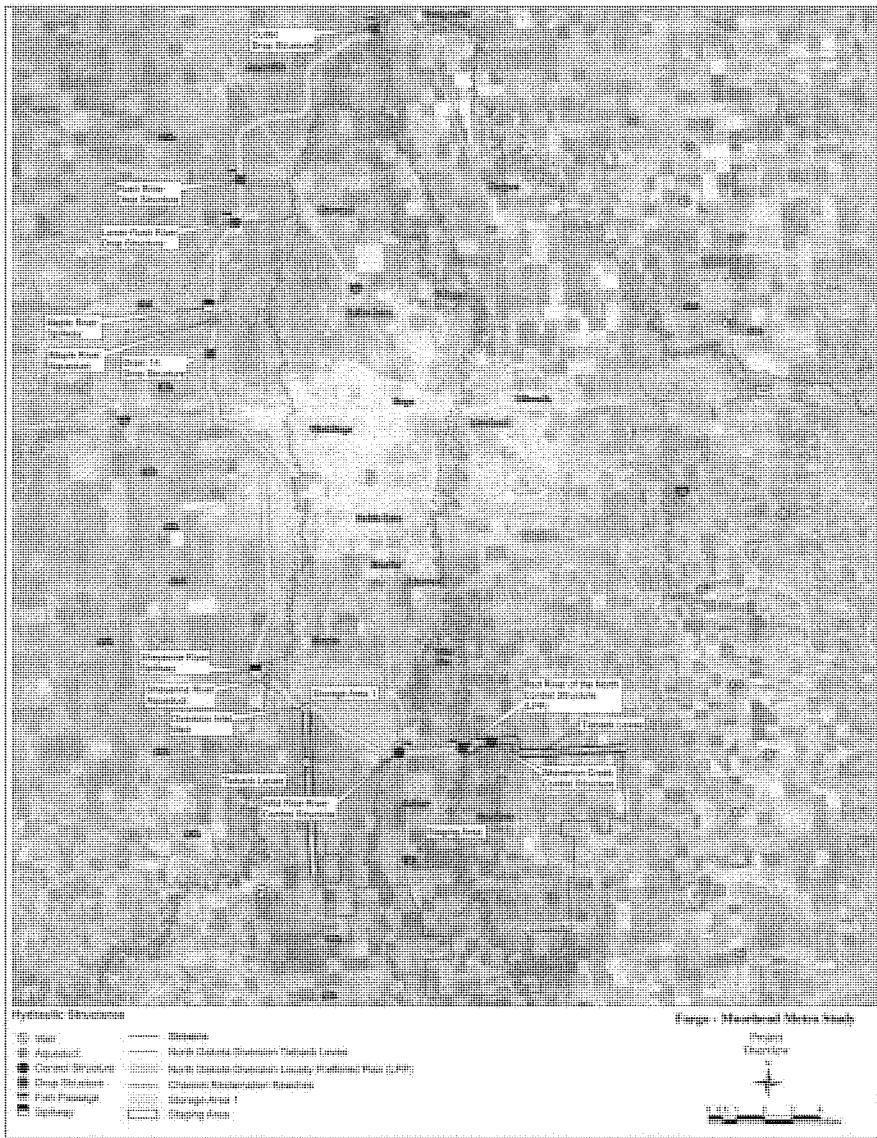
The plan consists of the following primary features:

- Red River control structure
- Connecting channel (Red River to Wild Rice River)
- Wild Rice River control structure
- Diversion inlet weir (at Cass County Road 17)
- Storage Area 1 (levees and flowage area)
- Upstream staging area (with non-structural mitigation)
- Main diversion channel

- Sheyenne River aqueduct and spillway structures
- Maple River aqueduct and spillway structures
- Lower Rush River drop structure with fish passage
- Rush River drop structure with fish passage
- Outlet drop structure (with adjacent fish passage)
- Wolverton Creek control structure
- Tie-back levees
- Side ditch inlet structures
- Highway bridges
- Railroad bridges
- I-29, US75 road raises and BNSF railroad raise in staging area

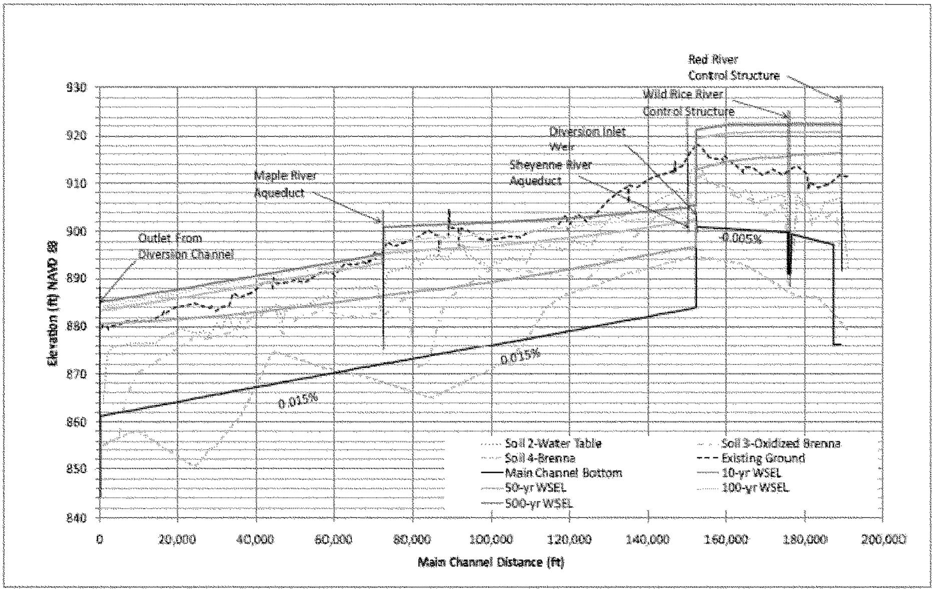
Figure 27 shows the alignment of the major features.

Figure 27 – LPP Diversion Alignment and features



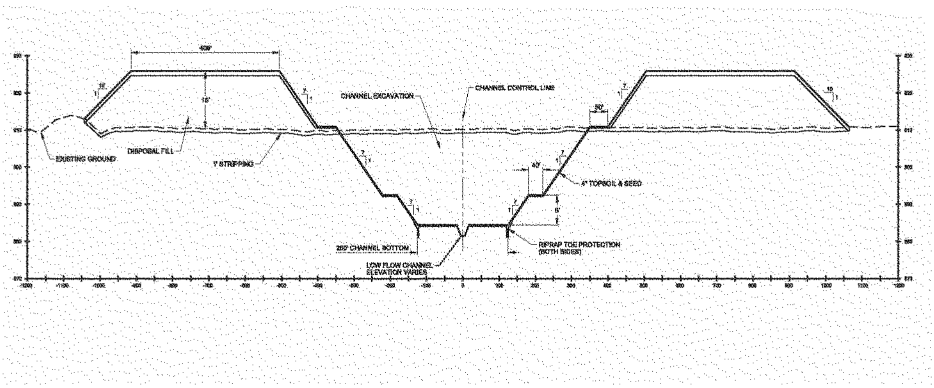
The LPP channel capacity was modified from previous phases to account for the storage and staging areas that were included. The inclusion of these areas allowed for the capacity of the diversion channel to be reduced to approximately 20,000 cfs. The diversion channel geometry was refined from Phase 3 based on required conveyance capacity, water surface elevation in the diversion, and limiting the excavation quantities of Brenna clays. The channel was designed to keep the 1-percent chance event flood flows below existing ground in the diversion channel as much as possible to limit impacts to drainage outside the channel. Figure 28 shows the channel profile, existing ground surface elevations, and the water surface elevations during various flood events. The right side of the figure is the upstream (south) end.

Figure 28 – LPP Channel Profile



The typical depth for the diversion is approximately 20 feet, with a maximum depth of 35 feet near the inlet weir. The channel bottom width between the Red and the Wild Rice rivers is 250 feet. Between the Wild Rice River and the diversion inlet weir, the bottom width is 100 feet, and downstream of the diversion inlet weir the width is 250 feet.. Generally all side slopes are 1V on 7H and some slopes include benching of varying widths, see Figure 29. A low flow pilot channel would run along the bottom of this reach, and erosion protection at the toe of the main channel side slopes would be provided. Soil excavated to construct the channel would be piled adjacent to the channel to a maximum height of 15 feet. The soil disposal piles would be as wide as necessary to contain the excavated material. The spoil slopes are 1V on 7H and 1V on 10H for the diversion side and outside slopes respectively. Portions of the soil disposal piles would be constructed to serve as levees when the water surface in the channel is higher than the natural grade. The total footprint of the LPP diversion channel has a maximum width of 2,200 feet including areas for soil disposal piles. The affected acreage is 8,054 acres.

Figure 29 – LPP Typical Cross Section



The main hydraulic structures controlling the flows passing into the protected area during the larger flood events are the control structures proposed on the Red River of the North and Wild Rice River, with effective flow widths of 150 feet and 60 feet, respectively. The Red River Control Structure is illustrated in Figure 30 and Figure 31. These gated structures would be operated only when the forecasted peak flow of the incoming hydrograph in the Red River of the North at the USGS gage in Fargo is greater than 9,600 cfs (approximately a 28-percent chance event). Otherwise, the structure (with fully open gates) resembles a bridge. Secondary bypass channels for fish passage are included at both of these structures.

Figure 30 - Red River Control Structure visualization (normal conditions—no flooding)

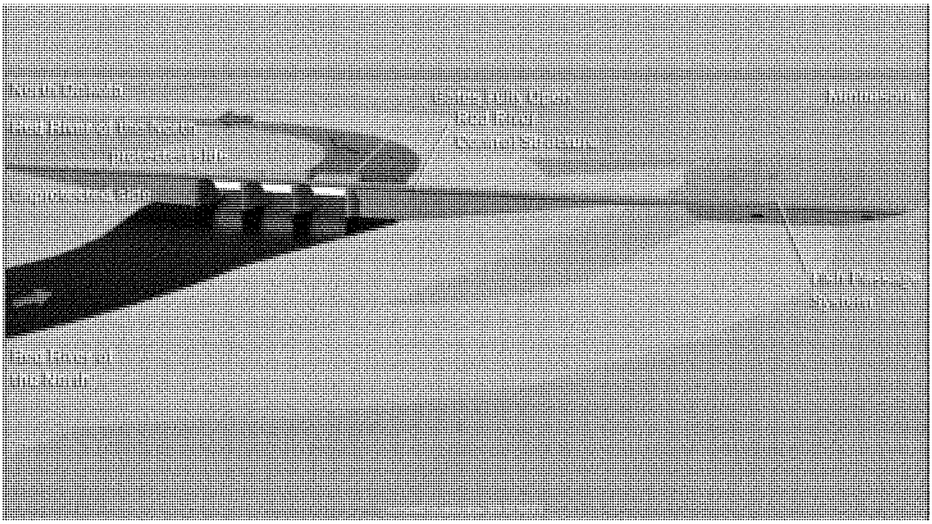
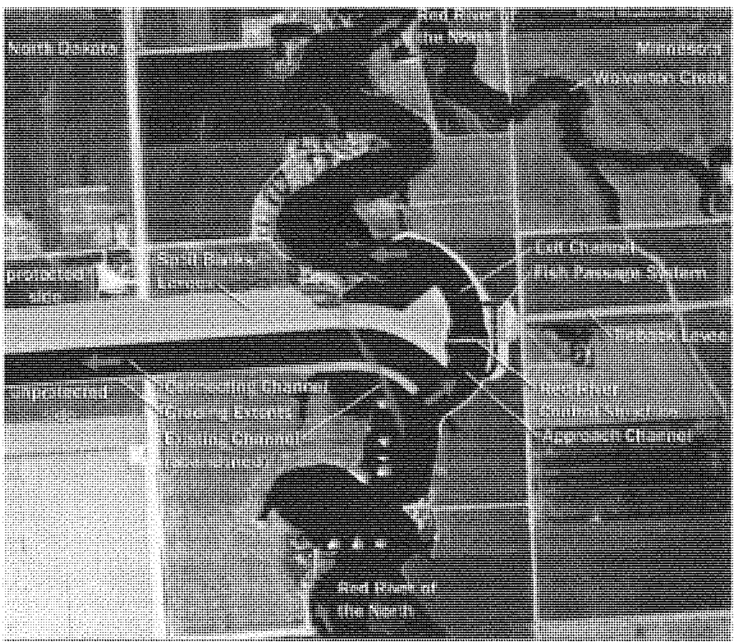


Figure 31 – Red River Control Structure visualization with flooding.

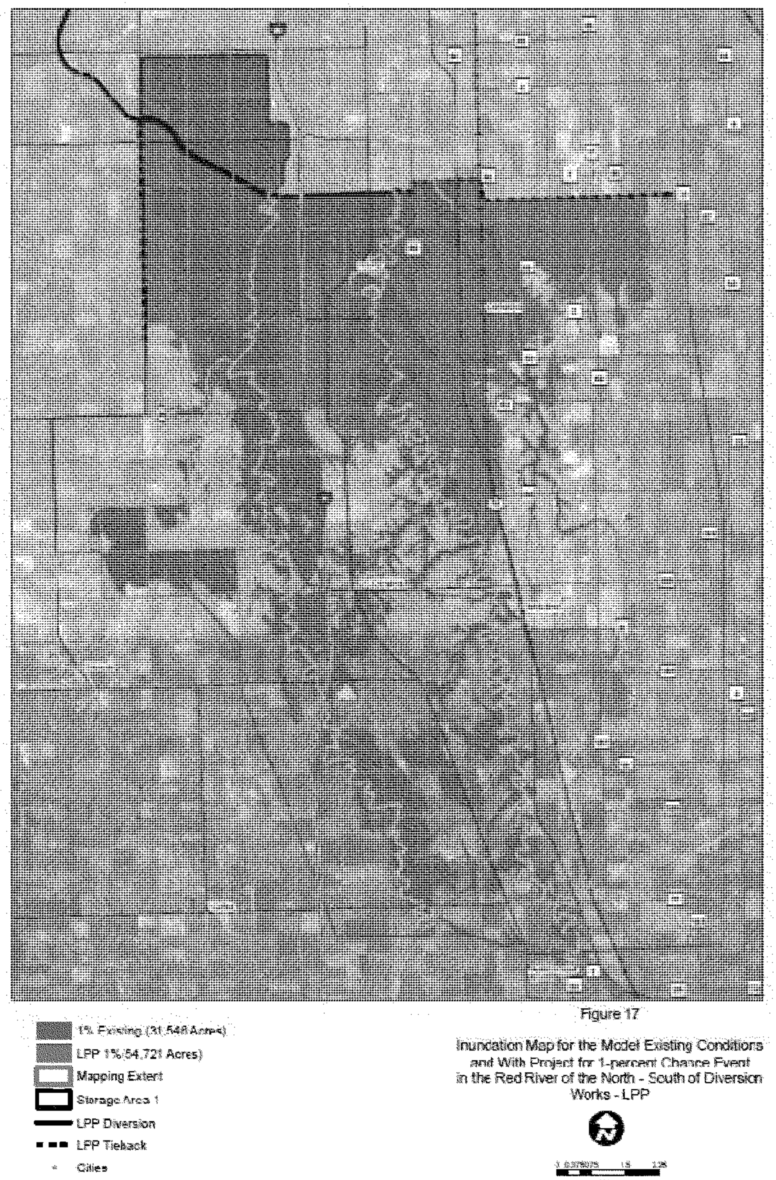


The diversion inlet structure is a passive weir (no gates or other regulation controls) with an effective flow width of 90 feet and a concrete spillway. The inlet weir is located where the diversion channel crosses Cass County Highway 17 south of Horace, ND.

The main line of flood protection at the south end of the project includes the embankments adjacent to the diversion channel, Storage Area 1 embankments, and a tie-back levee from the Red River control structure to high ground in Minnesota. A small control structure consisting of two 10-foot by 10-foot gated box culverts would be used where Wolverton Creek crosses the Minnesota tie-back levee. The structure would normally be open to allow the creek to pass through the levee, but during floods the structure would be closed to prevent flood flows from passing.

In order to nearly eliminate downstream impacts, upstream staging and storage of approximately 200,000 acre-feet immediately upstream of the diversion channel inlet would be required. Figure 32 shows the area that would be affected by staging during a 1-percent chance flood event. The Red River and Wild Rice River control structures would be operated to limit flows in the natural channels and raise water surface elevations in the upstream staging and storage areas. Water levels would rise to 922.8 feet at the inlet during a 1-percent chance event. The diversion inlet weir elevation is 903.25 feet. Storage Area 1 is a 4,360-acre area on the north side of the LPP diversion channel between the Wild Rice River and the Sheyenne River that will be formed by nearly 12 miles of embankments. Storage area 1, combined with staging in the floodplain, will nearly eliminate impacts from the project on flood levels downstream of the diversion channel outlet. The diversion works would be operated not only based on peak flows but primarily based on total hydrograph volumes, in particular those during the rising limb of the hydrograph. A tie-back levee along Cass County Road 17 (CR17) would be needed to keep staged water from crossing overland into the Sheyenne River. The levee would include construction of a ditch to capture local and overland flows. A portion of the CR17 tieback levee would be at an elevation lower than the other tie-back levees in order to act as an emergency spillway for extreme events that exceed the 0.2-percent chance event design capacity of the project.

Figure 32 – 1-percent chance event inundation map showing existing conditions (blue) and with LPP (red)



Hydraulic structures, known as aqueducts, would be located where the diversion crosses the Sheyenne and Maple rivers. The Maple River structure is illustrated in Figure 33 and Figure 34; the Sheyenne River aqueduct would be similar. The aqueducts would allow flows in the diversion to pass underneath the existing river channel, while allowing non-flood flows to continue down the Sheyenne and Maple rivers. During floods on the Sheyenne and Maple rivers, flows in excess of a 50-percent chance event would be diverted into the diversion channel. The 50-percent chance event flows are intended to maintain existing geomorphologic processes and existing habitat conditions in the natural channels. The Sheyenne and Maple River structures would remain biologically connected and maintain fish passage to those rivers nearly all of the time. The two crossing structure systems are similar in concept; each include a drop structure to prevent headcutting on the tributary, a spillway and channel to control diversion of tributary flows, and a hydraulic structure to pass a limited flow over the diversion channel to maintain the desired flow in the tributary beyond the diversion channel.

The structures located at the Lower Rush River and Rush River would include a combination of a vertical drop (also proposed for Drain 14), with a total width of 60 feet and 100 feet at the Lower Rush River and Rush River, respectively; and a fishway consisting of 40 feet wide riffle-pool sequences that would extend from the tributary channel down to the low flow pilot channel of the diversion channel. Both tributaries would be diverted into the diversion channel during all flow conditions, and to compensate for the loss of less than 4 miles of existing channelized tributaries, the lower 11 miles of the low flow pilot channel in the diversion channel would be constructed with meanders.

The outlet structure located where the diversion returns to the Red River of the North would be a concrete spillway with a width of 250 feet. Although the maximum diversion flows at this location are smaller in Phase 4 than in Phase 3, the LPP channel invert was raised above the invert of the ND35K plan, so there is greater vertical drop which required a change in the design at the outlet. A fishway would be constructed at the diversion channel outlet to allow fish access to the Rush and Lower Rush rivers via the low-flow channel in the diversion channel.

Figure 33 - Maple River crossing conceptual drawing

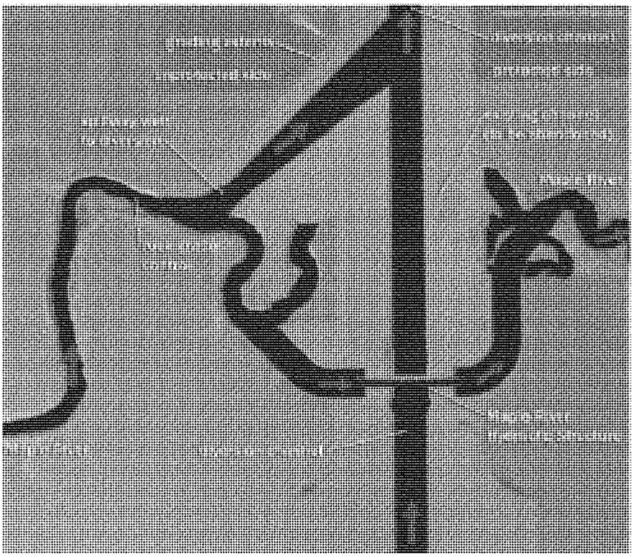
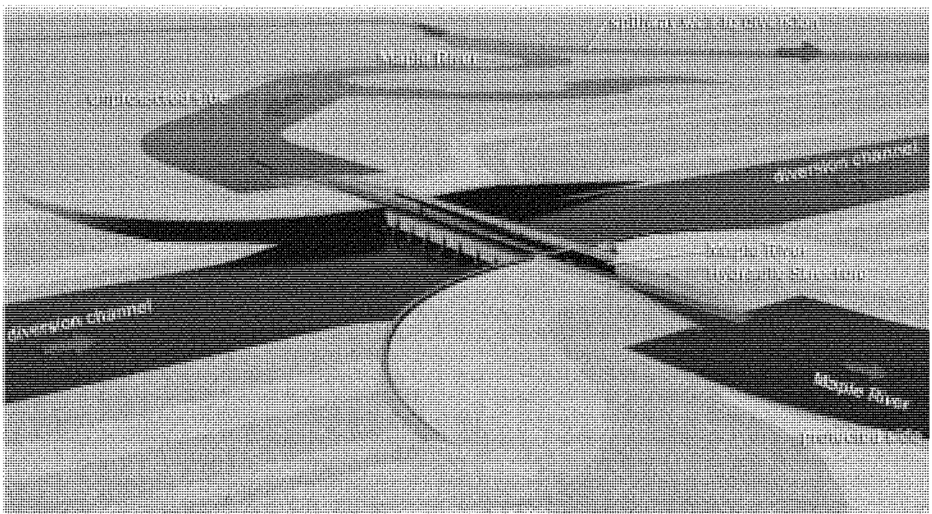


Figure 34 - Maple River Aqueduct visualization



3.7.3 North Dakota West and East Alignments

Prior to finalizing the North Dakota diversion alignment, it was proposed that the North Dakota West diversion alignment be given additional consideration based on information provided by a number of local entities. The North Dakota West alternative was initially eliminated from further consideration because it was believed at the time that there were no significant unique benefits or avoidance of any adverse environmental effects associated with the North Dakota West alignment (see section 3.4 for more details).

The North Dakota West alignment generally runs 1.5 miles to the west of the North Dakota East Diversion between Horace, ND and West Fargo. A formal request to consider moving the diversion to the West alignment was based on local concerns that were identified during the comment period that was held for the Notice of Intent to prepare a Supplemental Draft Environmental Impact Statement, which was published in the Federal Register on December 27, 2010.

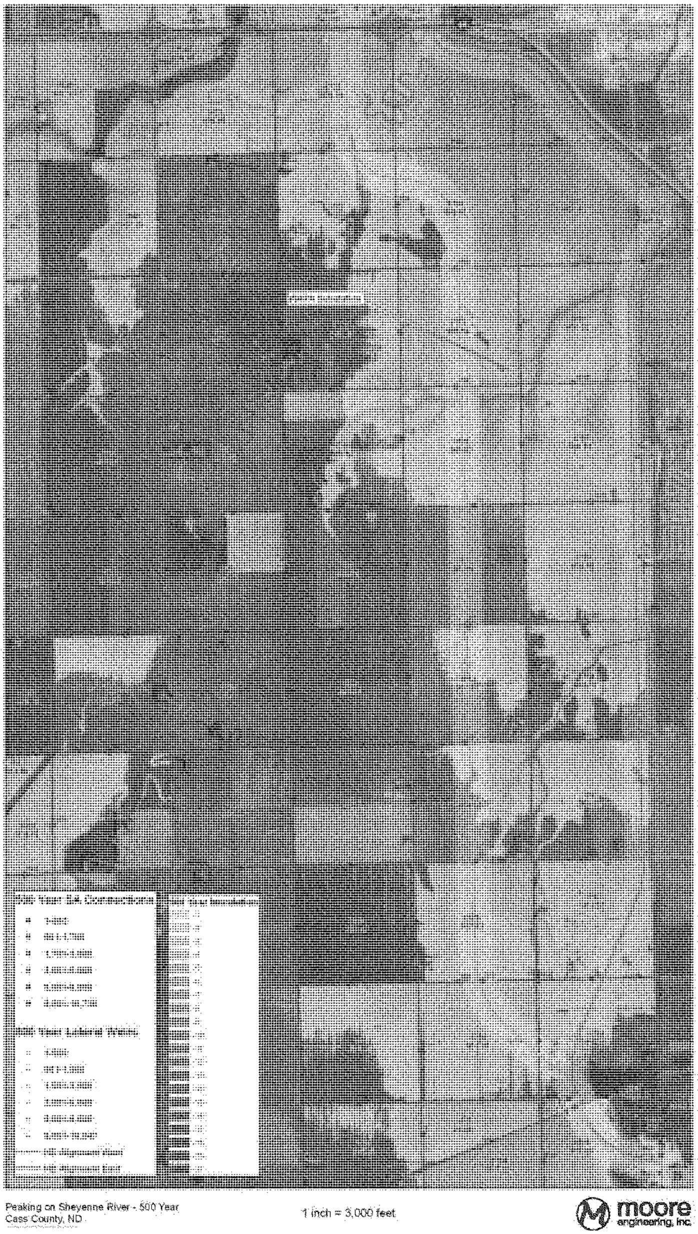
Comparisons between the East and West alignments were based on the following:

- Western Area Power Administration substation
- Impacts to natural resources including wetlands and floodplains
- Benefits to additional homes and emergency access
- Benefit of a straighter channel and interaction with existing diversions
- Level of protection for the existing community of West Fargo
- Benefits to local communities of developing in former floodplain areas

3.7.3.1 Western Area Power Administration substation

The Western Area Power Administration (WAPA) substation is located approximately 1 mile to the west of the existing Horace to West Fargo diversion and 3 miles to the south of I-94. The substation serves the Fargo-Moorhead Metro area with power and is a critical piece of infrastructure. The Fargo-Moorhead Metro area also has two other substations serving the area that are currently flood prone and are benefited with either North Dakota diversion alignment. The WAPA substation was constructed to an elevation between 907 and 909. Although the facility has been built to a relatively high elevation, access to the facility during flood events can be limited. The facility has built in redundancy including back-up transformers, and the critical aspects of the facility are all overhead. The overall power system in the region also has redundancy built in; however during large flood events there would likely be threats to other facilities that serve the region.

Figure 35 – Sheyenne River Floodplain – 0.2-percent chance event.



The Sheyenne River floodplain can be seen in Figure 35 for the 0.2-percent chance event (500-year). Although not clear on the map, the WAPA substation is not flooded. During the Sheyenne River 0.2 percent chance event flood levels near the WAPA substation reach an elevation of 905.5. Therefore the WAPA substation is 1.5 feet higher than the 0.2-percent chance event and generally not subject to direct flooding except from extremely large and infrequent flood events.

Access to the facility can be limited during flood events and this occurred during the flood of 2009 when access was limited from all directions. During flood events up to nearly the 1-percent chance event, access to the substation is open from the west, however events exceeding the 1-percent chance would result in no road access from any direction.

Due to the relatively high elevation of the WAPA substation, the fact that two other substations will be protected in the region, and that access is maintained up to nearly a 1-percent chance event, there would be limited risk reduction to the facility by locating it within the protected area. The WAPA is responsible for the facility; if WAPA believes there is a significant risk to the facility or the region's power supply, measures could be taken that address the situation much sooner than they could be addressed by the proposed diversion project.

3.7.3.2 Impacts to natural resources including wetlands and floodplains

The West alignment would impact 208 acres of wetlands; the East alignment would impact 150 acres of wetlands. Although either plan has impacts to wetlands, they are primarily farmed wetlands. Therefore, the general quality of these wetlands is poor and they provide minimal habitat value.

The West alignment would remove 9.2 square miles of the 1-percent chance event Sheyenne River floodplain. Removing this area from the floodplain essentially results in lost storage. As was found with previous modeling of the downstream impacts, when areas were removed from the floodplain and storage was lost there were downstream impacts. Therefore, the removal of this area from the floodplain would likely cause downstream impacts during a 1-percent chance event on the Sheyenne River with a coincidental flow event on the Red River. The study has been primarily focused on the Red River event with coincidental flow events on the tributaries and no models have been developed to assess the exact impact, however it can be said with certainty that there would be impacts.

3.7.3.3 Benefits to additional homes and emergency access

The West alignment would provide benefits to additional homes as a result of removing the 9.2 square miles from the floodplain. This includes the Willow Creek subdivision with 24 homes. The homes in the area would be benefited by relocating the diversion to the West alignment.

Emergency access during flood events is critical both to ensure that the public can be assisted by emergency personnel and to ensure they can evacuate the area during flood events. Interchange 324 on I-94 was identified by local officials as critical to the emergency services in the area. The elevations of the interchange are all above the existing 1-percent chance event Sheyenne River floodplain, however the roadways to the north and south would be inundated by flood waters. The exception to this would be for the additional 9.2 square miles of benefited area that could be accessed during a flood event with the West alignment.

Properties to the northeast of the interchange would be within the benefited area of either alignment and access to these areas can be obtained by other routes such County Road 10 or 17.

3.7.3.4 Benefit of a straighter channel and interaction with existing diversions

The existing Sheyenne Diversion project consists of two parts: the Horace to West Fargo diversion and the West Fargo diversion. Both the East and West Fargo-Moorhead Diversion alignments make the existing Horace to West Fargo diversion channel unnecessary. With either alignment the existing Horace to West Fargo diversion would be abandoned. The portion of the existing Sheyenne Diversion from West Fargo to its outlet (the West Fargo diversion) would remain to divert Sheyenne River flows around West Fargo.

Significant analysis and data collection has gone into the development of the diversion channel design. As can be seen in Appendix I, Geotechnical Engineering, direction changes in the alignment are not anticipated to have significant erosion or operational issues; neither alignment would be considered superior to the other from a technical standpoint. Lessons learned from the existing Sheyenne Diversion project have been incorporated to ensure that any diversion channel will be stable.

In sum, either the East or West alignment will provide a significantly greater level of risk reduction from flooding from the Sheyenne River, and both alignments would include similar modifications to the existing Sheyenne Diversion project.

3.7.3.5 Level of protection for the existing city of West Fargo

The city of West Fargo is subject to flooding from the Red River for events larger than the 1-percent chance event and would be entirely inundated during a 0.2-percent chance Red River flood event. Either diversion channel alignment would provide a significant level of flood risk reduction to the community of West Fargo from the Red River flooding.

West Fargo is also threatened from Sheyenne River flooding. The existing Sheyenne Diversion consists of two portions, the Horace to West Fargo diversion and the West Fargo diversion. The Horace to West Fargo portion can safely pass approximately a 1-percent chance Sheyenne River flood event. The West Fargo portion can safely pass a Sheyenne River flood event in excess of the 0.2-percent chance event. Either the proposed North Dakota East or West diversion would significantly reduce the flood risk along the Sheyenne River between Horace and West Fargo.

3.7.3.6 Benefits to local communities of developing in former floodplain areas

The Corps of Engineers and other federal agencies must comply with Executive Order (EO) 11988 Floodplain Management when designing or permitting projects. One goal of EO 11988 is to "avoid direct or indirect support of floodplain development wherever there is a practicable alternative." If avoiding the floodplain altogether is not practicable, EO 11988 requires federal agencies to "minimize potential harm to or within the floodplain." The communities of West Fargo, Horace, and Cass County have indicated a desire to develop into areas that are currently floodplain and subject to regular flooding. They have developed long term goals to develop in the floodplain areas that would be between the East and West diversion alignments and would like to see these areas removed from the floodplain. While the West diversion alignment would significantly reduce flood risk from riverine flooding, much of the area between the East and West alignments is extremely low and would still be threatened during large rain events. Allowing citizens to build in the existing floodplain would increase overall flood damages in the future. Flooding could also impact emergency access in these areas and cause catastrophic loss during rainfall flood events. As can be seen in Figure 35 the area proposed for development has significant flooding today, however there are areas depicted on the map just to the west that would not be in the existing 0.2-percent chance event floodplain and would provide practicable alternatives for future development.

3.7.3.7 Conclusion on East Alignment versus West Alignment

Based on the items listed above that have been individually and collectively considered, the North Dakota West diversion channel is screened from further consideration. The East alignment will have less impact to the floodplain, less overall impact to wetlands, and will provide no appreciable benefits to the WAPA substation. Although the West alignment would reduce flood risk to existing homes, the loss of floodplain and the likelihood of future damages in low-lying areas outweighs the potential economic benefits from the federal perspective.

The East alignment minimizes floodplain impacts, provides a reasonable balance between protecting existing development and preserving the floodplain, and is a practicable alternative to the West alignment.

<u>3.7.4 Southern Alignment for North Dakota Diversion</u>

Local entities including Oxbow, ND and Cass County requested that consideration be given to moving the inlet of the North Dakota diversion south of Oxbow to reduce flood risk for the towns of Oxbow and Hickson, as well as the Bakke Subdivision.

An initial assessment was completed. It was determined that moving the diversion alignment south would have several adverse consequences. These consequences are due in part to the fact that moving the diversion south of Oxbow would take additional land out of the floodplain, which would require additional storage. South of Oxbow, the land rises more quickly, which reduces the available storage volume on each acre of land. To get an equivalent storage volume and to account for the additional land taken out of the floodplain, the depth of staging would need to be increased approximately 2.5 feet, requiring higher control structures and tie-back levees. This would impact communities further upstream and raise additional technical challenges associated with the higher structures and levees. Moving the alignment south from its proposed location would also have implications under EO 11988 which could make it unacceptable from a federal perspective, as the proposed alignment is a practicable alternative to the Southern alignment.

<u>3.7.5 Distributed Flood Storage versus Upstream Staging and Storage</u>

The 200,000 acre feet of staging and storage as part of the LPP is effective and reliable storage. The further away storage is located from Fargo-Moorhead, the less effective and reliable it becomes and the smaller the benefits. To have an equal amount of effective storage further upstream, other studies have estimated that 2-5 times more storage is required. The total acre-feet required would be significantly more than what is needed with the LPP. This is because of the fact that the storage would have to be located in the right place for each particular flood event. To implement the effective storage upstream equal to the 200,000 acre feet in the storage and staging areas would require many sites, which would result in greater impacts to more people, property, agriculture, and the environment. Storage would likely require upwards of 60,000 acres. It would also be necessary to construct structural features to contain the water. Even if distributed storage were feasible it would be very difficult to implement on a large scale due to the number of sites required, the technical challenges to operate all of the sites, and the environmental impacts of the large area that would be impacted. The North Dakota State Water Commission published a paper titled Flood Retention: Not Always the Silver Bullet, referenced in Section 1.5.1.9, which reached similar conclusions.

Based on that information, distributed storage is screened from further consideration as an alternative to upstream staging and storage. The upstream staging and storage is more implementable from a logistical perspective, will have greater reliability, and will have less overall impacts than distributed storage.

3.7.6 Consideration of 20-percent flow reduction

The Red River Basin Commission has proposed a 20-percent flow reduction plan to reduce flood damages to the basin. The plan for 20-percent flow reduction is based on the 1997 flood, which is a relatively small flood event in the Fargo-Moorhead area of 28,000 cfs. The 20-percent reduction would provide some benefits for that event, but it would not significantly reduce the flood risk to the Fargo-Moorhead area. The proposed diversion project is designed for flows in excess of 61,000 cfs. To achieve the 20-percent reduction for a large flood event, such as 61,000 cfs, would require much more storage than is practical to implement upstream of Fargo-Moorhead, due to the number of sites required, and the availability of sites. Even if it was possible to construct enough upstream storage to reduce a 0.2-percent (500-yr) event by 20-percent, the resulting peak flow of 48,800 cfs at the Fargo gage would exceed that seen in 2009 by more than 60-percent. In addition, the large acreage required to implement the 20-percent flow reduction plan would have an impact on property owners, agriculture, and the environment.

Based on that information the 20-percent flow reduction is screened from further consideration.

3.7.7 Flows from Devils Lake

Flows from Devils Lake could have both a water quantity and water quality impact on the Fargo-Moorhead area. If Devils Lake were to overtop, flow estimates for a controlled overflow are 3,000 cfs and flow estimates for an uncontrolled overflow with erosion are approximately 14,000 cfs. If a North Dakota alignment diversion channel (LPP or ND35K) were in place, it would have the capacity to capture those flows during flood events and provide flood risk management benefits to the communities. With a Minnesota alignment diversion channel (FCP) or no diversion channel, the communities could be subject to additional flooding if the flows from Devils Lake were coupled with a spring or summer flood event.

3.8 COMPARISON OF ALTERNATIVES

Comparison of alternatives is the fifth step in the planning process, which is based on the evaluation of the impacts of the alternatives, the fourth step in the planning process. The more detailed evaluations of the impacts of the alternatives are presented in Chapter 5, Environmental Consequences.

3.8.1 Comparison of Plan Features

Features of the alternative plans (LPP, FCP, and ND35K) are displayed in a comparative format on Table 10. The costs of these features are included on Table 11, also in a comparative format.

Table 10 – Final Comparison of Alternative Plan Features

CHANNEL ALIGNMENT PARAMETERS	LPP	FCP	ND35K
Maximum top width (feet)	2200	2800	2450
Bottom width (feet)			
Maximum	250	400	300
Minimum	100	225	100
Diversion			
Maximum depth (from natural ground)	28	30	29
Excavation (million cu. yards)	55	55	67
Low flow channel (3 ft X 10 ft)	√	√	√
Length of diversion channel (miles)	36	25	36
Channel extension (miles)	--	3.69	--
Length of tie back levee (miles)	10.1	9.86	3.26
Height of levee (feet)	17	8	8
Length of Storage Area 1 levee (miles)	12	--	--
Height of Storage Area 1 levee (feet)	17	--	--
Acres of flood storage area	4360	--	--
Number of houses in diversion footprint	6	5	6
Acres in project footprint (diversion & levees)	8054	6415	6560
Acres of wetlands impacted - worst case	1153	976	1053
Hydraulic structures			
Drop structures	4	1	3
River crossings	6	0	6
Highway bridges	19	20	18
Railroad bridges	4	4	4
Stage at Fargo gage			
0.2 % chance event (500yr) (ft)	40	39.6	40
1% chance event (100yr) (ft)	30.8	31.9	30.6
Stage impacts for 1% chance event			
Downstream max stage increase (inches)	3.5	12.5	25
Number of structures impacted downstream	1533*	3616*	3405*
Upstream max stage increase (inches)	98.8	6.8	0.2
Number of structures impacted upstream	838**	36	--
Land removed from 1% floodplain (sq. miles)	69	30	80

* Calculated to Drayton, ND

** Including Storage Area 1, Staging Area and structures upstream of the Staging Area

Table 11 – Final Comparison of Alternative Plan Costs including Recreation (October 2011 Price Level)

Account	Item	**LPP**	**FCP**	**ND35k**
01	Lands & Damages	278,372	73,617	66,076
02	Relocations	154,291	109,709	110,444
06	Fish and Wildlife Facilities	61,987	25,053	100,261
08	Roads, Relocations and Bridges	60,045	164,383	65,590
09	Channels & Canals	783,778	604,135	877,583
11	Levees, Floodwalls, & Floodproofing	143,435	25,328	3,983
14	Recreation Facilities	29,800	25,845	31,832
30	Planning, Engineering and Design	183,850	142,249	182,714
31	Construction Management	85,790	66,382	85,265
	Total First Costs	**$1,781,348**	**$1,236,701**	**$1,523,748**
	Annual OMRR&R Diversion Cost	$3,501	$3,508	$3,436
	Annual OMRR&R Recreation Cost	$130	$40	$130
	Toal Annual OMRR&R	$3,631	$3,548	$3,566
	All costs in thousands ($1,000)			

3.8.2 System of Accounts

3.8.2.1 Methodology

The Economic and Environmental Principles for Water and Related Land Resources Implementation Studies, established by the Water Resources Council in 1983, created four accounts to facilitate evaluation and effects of alternative plans:

- The national economic development (NED) account displays changes in the economic value of the national output of goods and services
- The environmental quality (EQ) account displays non-monetary effects on significant natural and cultural resources
- The regional economic development (RED) account registers changes in the distribution of regional economic activity that result from each alternative plan.
- The other social effects (OSE) account registers plan effects from perspectives that are relevant to the planning process, but are not reflected in the other three accounts.

3.8.2.2 National Economic Development (NED)

The intent of comparing alternative flood risk management plans in terms of national economic development is to identify the beneficial and adverse effects that the plans may have on the national economy. Beneficial effects are considered to be increases in the economic value of the national output of goods and services attributable to a plan. Increases in NED are expressed as the plan's economic benefits, and the adverse NED effects are the investment opportunities lost by committing funds to the implementation of a plan. Comparison of the plans under consideration using the NED account is shown in Table 12. The values for net benefits shown on the tables are the differences between the average annual economic benefits and the average annual cost associated with each plan. As shown in Table 9 the current annual net benefits of the

MN40K plan are the greatest, and the MN40K plan is therefore the NED plan. However, as explained in section 3.6.5, it was not necessary to fully describe the NED plan once it was demonstrated that the LPP was a smaller capacity plan, and the NED plan was dropped from further consideration. The MN35K plan, the FCP, was kept for comparison to the LPP for cost-sharing purposes.

The no action alternative has zero net benefits and results in equivalent annual damages in excess of $194.8 million.

Table 12 - National Economic Development (NED) Account (all dollar values in thousands)

	LPP	FCP	ND35k
Total Diversion First Cost	$1,745,033	$1,205,207	$1,484,913
Interest During Construction and Discounting	$296,914	$232,405	$252,655
Present worth of Investment	$2,041,947	$1,437,611	$1,737,568
Annualized Investment Cost	$97,097	$68,360	$82,623
Annual OMRR&R Cost	$3,501	$3,508	$3,436
Induced Damages	$0	$153	$153
Average Annual Diversion Charges	$100,598	$72,021	$86,212
Total Recreation First Cost	$36,315	$31,494	$38,835
Interest During Construction and Discounting	$791	$2,015	$801
Present worth of Investment	$37,106	$33,509	$39,636
Annual Recreation First Cost	$1,764	$1,593	$1,885
Annual Recreation OMRR&R Cost	$130	$40	$130
Average Annual Recreation Charges	$1,894	$1,633	$2,015
Flood Damage Reduction Benefit	$162,800	$164,800	$162,800
Flood Proofing Cost Savings	$10,430	$6,240	$10,017
Flood Insurance Adminstrative Cost Saving	$960	$1,000	$960
Incremental Non-Structural Flood Risk Benefit	$627	$414	$0
Avg. Annual Diversion Benefit	$174,817	$172,454	$173,777
Avg. Annual Recreation Benefit	$5,130	$5,355	$5,130
Annual Net Diversion Benefit	**$74,219**	**$100,433**	**$87,565**
Annual Net Recreation Benefit	$3,236	$3,722	$3,115
Total Annual Net Benefit	$77,455	$104,155	$90,680
Diversion Benefit-Cost Ratio	**1.74**	**2.39**	**2.02**
Recreation Benefit-Cost Ratio	2.71	3.28	2.55
Benefit-Cost Ratio	**1.76**	**2.41**	**2.03**

1. Costs and Benefits are given in $1,000's
2. Assumes a 50 year period of analysis - 4 1/8% interest rate.
3. Assumes a 7.5 year period of construction for MN diversions and 8.5 years for ND diversions
4. No credit is given to flood fight reliability
5. Base Year is 2019.
6. All figures in October 2011 dollars
7. Non-Structural Costs are included in Diversion Costs

3.8.2.3 Environmental Quality (EQ)

The environmental quality account is another means of evaluating the alternatives to assist in making a plan recommendation. The EQ account is intended to display the long-term effects that the alternative plans may have on significant environmental resources. Significant environmental resources are defined by the Water Resources Council as those components of the ecological, cultural and aesthetic environments which, if affected by the alternative plans, could have a material bearing on the decision-making process. Significance is derived from institutional, public or technical recognition that a resource or an effect is significant. A comparison of the effects that the diversion channel alternatives may have on the EQ resources is shown in Table 13.

Table 13 – Environmental Quality (EQ) Account

	Alternatives			
Resources	**No Action**	**LPP**	**FCP**	**ND35K**
Flooding	Expected Annual Flood Damage of $194.8 million	Expected Annual Flood Damage reduced by $162.8 million	Expected Annual Flood Damage reduced by $164.8 million	Expected Annual Flood Damage reduced by $162.8 million
Air Quality	No Effect	Minor degradation from extensive and lengthy construction period	Minor degradation from extensive and lengthy construction period	Minor degradation from extensive and lengthy construction period
Water Quality	No Effect	Temporary minor adverse impacts on surface w ater quality during construction.	Temporary minor adverse impacts on surface w ater quality during construction.	Temporary minor adverse impacts on surface w ater quality during construction.
Erosion and Sedimentation	Continued Erosion during flooding	No significant geomorphic issues	No significant geomorphic issues	No significant geomorphic issues
Water Quantity	No Effect	Dow nstream stage increase 0.5-3.5 inches, upstream stage increase 1.3-98.8 inches, 1 percent event	Dow nstream stage increase 0.7-12.5 inches, upstream stage increase 6.8 inches, 1 percent event	Dow nstream stage increase 7.6-25.4 inches, upstream stage increase 0.1-0.2 inches, 1 percent event
Ground Water	No Effect	Slightly low ered w ater table near diversion channel	Slightly low ered w ater table near diversion channel	Slightly low ered w ater table near diversion channel
Aquifers	No Effect	Small potential to influence aquifers	Small potential to influence aquifers	Small potential to influence aquifers
Aquatic Habitat	Improved due to ongoing efforts to improve fish passage	Loss of 46 acres of habitat w ith structures at Red River and tributaries. Potentially significant impacts to aquatic species migrational corridors	Loss of 10 acres of habitat w ith large closure structure at Red River. Less than significant impacts to aquatic species migrational corridors	Loss of habitat of approximately 37 acres w ith large structures at 6 rivers. Less than significant impacts to aquatic species migrational corridors

	Alternatives			
Resources	**No Action**	**LPP**	**FCP**	**ND35K**
Riparian Habitat	No Effect	Increase in habitat value for approximately 1900 acres in the form of grass sw ale near the bottom of the diversion. Loss of 118 acres at river connections and along channel.	Increase in habitat value for approximately 2,000 acres in the form of grass sw ale near the bottom of the diversion. Loss of 42 acres at river connections	Increase in habitat value for approximately 1900 acres in the form of grass sw ale near the bottom of the diversion. Loss of 118 acres at river connections and along channel.
Wetlands	No Effect	Could directly or indirectly impact approximately 1153 acres of w etlands	Could directly or indirectly impact approximately 976 acres of w etlands	Could directly or indirectly impact approximately 1053 acres of w etlands
Upland Habitat	No Effect	Potential for increased habitat benefit	Potential for increased habitat benefit	Potential for increased habitat benefit
T and E species	No Effect	No Effect	No Effect	No Effect
Floodplains (E.O. 11988)	112 sq miles in floodplain during .01 year event out of 261 sq miles in project area	37.5 sq miles remain in floodplain. 69.8 sq miles taken out of floodplain during 1-percent chance event	80.9 sq miles remain in floodplain, 31.3 sq miles taken out during a 1-percent chance event	30.7 sq miles remain in floodplain. 81.3 sq miles taken out of floodplain during 1-percent chance event
Cultural Resources	No Effect	Potential for impacts along diversion channel. Higher potential for impacts along the river banks	Potential for impacts along diversion channel. Higher potential for impacts along the river banks	Potential for impacts along diversion channel. Higher potential for impacts along the river banks
Prime and Unique Farmland	No Effect	Approximately 6878 acres of prime and unique farmland w ill be removed	Approximately 5889 acres of prime and unique farmland w ill be removed	Approximately 6540 acres of prime and unique farmland w ill be removed
Economic Resources	Continued potential for property damage and business losses due to damaging flood events.	Significant reduction in property damage and lost business.	Significant reduction in property damage and lost business.	Significant reduction in property damage and lost business.

3.8.2.4 Regional Economic Development (RED)
The regional economic development account is intended to illustrate the effects that the alternatives would have on regional economic activity, specifically, regional income and regional employment. The comparison of possible effects that the plans may have on these resources is shown in Table 14. The completed RED analysis is included in Appendix C, Economics. The RED analysis only analyzed the MN20K, MN35K and ND35K plans. These plans were selected for analysis based on the likelihood of one of those plans ultimately being selected as the recommended plan. This analysis was completed based on the information contained in Table 7 and was not updated to reflect the final analysis. The RED analysis shows that the regional changes in economic output for the MN20K, MN35K and ND35K range between $323 and $332 million annually.

Table 14 – Regional Economic Development (RED) Account

	Without Project Conditions	North Dakota East 35K cfs	Minnesota Short 35K cfs	Minnesota Short 20K cfs
Changes in Economic Output*		$332,455	$329,715	$323,755
Annual Net Change in Employment	(1,665)	895	815	677
Changes in Tax Revenues*	$(5,900) - (18,600)	$12,109	$11,968	$10,922
Average Annual Benefits*		$67,355	$63,795	$54,390
Annual Regional Flood Damages*	$61,676	$8,007	$11,042	$18,666
Changes in Annual Tax Revenue *	$(7,781)	$4,327	$3,917	$3,140
Annual Loss of Business Income*	$65,000			
Gross Regional Product Annual Growth Rate^	1.29 - 2.18	3.09 - 4.11	3.09 - 4.11	3.09 - 4.11

* $1,000 ^ %

3.8.2.5 Other Social Effects (OSE)
This section describes the Other Social Effects (OSE) component of the Fargo-Moorhead Flood Risk Management Feasibility Study. Implementing flood risk management alternatives could have varying impacts on the life of the residents and the social fabric of the communities in the study area. By considering the human impact and evaluating alternatives from an OSE perspective, the analysis can be used in alternative plan formulation and in the decision making process for choosing an alternative that maximizes social benefits.

Social well-being factors are constituents of life that influence personal and group definitions of satisfaction, well-being, and happiness. The distribution of resources; the character and richness of personal and community associations; the social vulnerability and resilience of individuals, groups, and communities; and the ability to participate in systems of governance are all elements that help define well-being and influence to what degree water resources solutions will be judged as complete, effective, acceptable, and fair. It is the OSE account that considers these elements and assures that they are properly weighted, balanced, and considered during the planning process under the Corps' Four Accounts Planning Framework.

A loss of life analysis was completed for the future without project condition and for the selected plan. (See Appendix D, Other Social Effects). The analysis for future without project conditions showed that a failure of emergency levees during large flood events could cause considerable loss of life. Assuming that the floodplains were 98% evacuated prior to an anticipated levee breach or overtopping, four deaths could be expected during a 1-percent chance event; the toll increases to 12 deaths for a 0.2-percent chance event. History has shown that residents in the study area do not evacuate, preferring to stay and maintain the emergency flood barriers. Assuming that the floodplains were not evacuated and an unanticipated failure of emergency levees occurred, expected deaths were estimated at 200 and 594 for the 1-percent chance and 0.2-percent chance events, respectively. With a diversion project in place, the potential for loss of life is expected to be significantly lower, as discussed in Section 3.10.4 and Appendix D. An engineered permanent project would be far less likely to fail and would significantly reduce the frequency, duration and magnitude of flood events in the developed areas.

The Corps uses seven social factors to describe the social fabric of a community. The social factors are based on conventional psychological Human Needs Theory and Abraham Maslow's Hierarchy of Needs. Table 15 lists and describes the social factors.

Table 15 – Social Factors

Social Factor	Description
Health and Safety	Refers to perceptions of personal and group safety and freedom from risks
Economic Vitality	Refers to the personal and group definitions of quality of life, which is influenced by the local economy's ability to provide a good standard of living
Social Connectedness	Refers to a community's social networks within which individuals interact; these networks provide significant meaning and structure to life
Identity	Refers to a community member's sense of self as a member of a group, in that they have a sense of definition and grounding
Social Vulnerability and Resiliency	Refers to the probability of a community being damaged or negatively affected by hazards, and its ability to recover from a traumatic event
Participation	Refers to the ability of community members to interact with others to influence social outcomes
Leisure and Recreation	Refers to the amount of personal leisure time available and whether community members are able to spend it in preferred recreational pursuits

Source: Handbook on Applying "Other Social Effects" Factors in Corps of Engineers Water Resources Planning (USACE, 2009).

A comparison of the effects that the diversion channel alternatives would have on OSE resources is shown on Table 16. The diversion channel alternatives considered all provide a high level of flood risk management, which results in the OSE impacts being similar for all of the diversion channel alternatives.

Table 16 – Other Social Effects (OSE) Account

	No Action	LPP	FCP	ND 35K
Public Health and Safety	High level of flood risk in entire region with associated stress and anxiety, risk to regional health care system, and impacts to emergency access during floods. High potential for loss of life during floodfights.	Project would significantly reduce risk to regional health care system and stress in F-M. No change to flood risk downstream. Overall reduction in upstream flood risk due to relocations out of the floodplain. Moderate increase in flood risk upstream where homes remain.	Project would significantly reduce risk to regional health care system and stress in F-M. Flood risk would slightly increase upstream and moderately increase downstream.	Project would significantly reduce risk to regional health care system and stress in F-M. Would increase flood risk downstream. No change to upstream flood risk.
Economic Vitality	Current regional economy is strong. If a catastrophic flood occurs, economic impacts will be extensive and long-lasting.	Project would significantly benefit the regional economy, especially in the F-M metro area. Minimal changes downstream. Significant impacts upstream in staging area and Storage Area 1--businesses would be relocated; agricultural use of land impacted; reduction of local tax base.	Project would significantly benefit the regional economy, especially in the F-M metro area. Slightly decreased economic vitality downstream due to increased flood stages. Slight decrease upstream due to increased flood stages. Reduction of local tax base due to loss of ag land due to channel construction.	Project would significantly benefit the regional economy, especially in the F-M metro area. Decreased economic vitality downstream due to increased flood stages. Little change upstream. Reduction of local tax base due to loss of ag land due to channel construction.
Social Connectedness	High levels of instrumental social support will continue throughout the region. Population of downstream communities will continue to decline following the historic trend.	Project would cause significant social disruption for communities within the staging area and Storage Area 1 (Oxbow, Hickson, Bakke Addition, Comstock). Metro area would see less frequent disruptions due to floodfights. Impacts to local road network could increase social separation for rural residents. Little change downstream.	F-M metro area would see less frequent disruptions due to floodfights. Impacts to local road network could increase social separation for rural residents. Slight change upstream in area with upstream impacts. Downstream residents would experience some increased social disruption during floods.	F-M metro area would see less frequent disruptions due to floodfights. Impacts to local road network could increase social separation for rural residents. Little change upstream. Downstream residents would experience some increased social disruption during floods.
Identity	Strong European heritage, welcome attitude toward immigration, work ethic and "fight and recover attitude" toward flood fighting will continue throughout the region.	Project would be detrimental for communities within the staging area and Storage Area 1 (Oxbow, Hickson, Bakke Addition, Comstock). Elsewhere, the project would not likely affect cultural and community identity significantly. Perception of metro versus rural bias may increase.	Project would not likely affect cultural and community identity significantly. Perception of metro versus rural bias may increase.	Project would not likely affect cultural and community identity significantly. Perception of metro versus rural bias may increase.
Social Vulnerability and Resilience	F-M Region is highly vulnerable to catastrophic flood damage, but residents would likely band together during recovery. Resilience of rural communities may be lower due to lack of temporary housing options. Low-income residents are more vulnerable to short-term impacts of flood fighting.	Project would significantly reduce the F-M metro area's vulnerability to floods, allowing them to focus on other social needs. Little change downstream. Overall reduction in upstream vulnerability due to relocations out of the floodplain. Moderate increase in vulnerability upstream where homes remain.	Project would significantly reduce the F-M metro area's vulnerability to floods, allowing them to focus on other social needs. Slight change upstream in areas with upstream impacts. Downstream vulnerability would increase slightly. Resilience of rural communities may be lower due to lack of temporary housing options.	Project would significantly reduce the F-M metro area's vulnerability to floods, allowing them to focus on other social needs. Little change upstream. Downstream vulnerability would increase. Resilience of rural communities may be lower due to lack of temporary housing options.
Civic Participation	Residents in the study area exhibit a high rate of participation in civic activities like flood fights, elections and public meetings.	Project would negatively affect civic participation of residents in upstream communities within the staging area and Storage Area 1. Little effect on participation by F-M metro and downstream residents.	Project has perceived disporportionate impacts to Minnesota residents that could affect civic participation. Slight impacts on upstream residents in area with upstream impacts. Downstream flood stage impacts could lead to a decrease in participation downstream.	Project has little effect on participation by F-M metro and upstream residents. Downstream flood stage impacts could lead to a decrease in participation downstream.
Leisure and Recreation	Residents of the region are active. Recreational facilities would continue to be provided in the communities as currently planned.	Project features would increase recreational opportunities and reduce time spent on flood fighting in the F-M metro area. Little change downstream.	Project features would increase recreational opportunities and reduce time spent on flood fighting in the F-M metro area. Little change upstream in areas with upstream impacts. Would slightly increase flood fighting downstream.	Project features would increase recreational opportunities and reduce time spent on flood fighting in the F-M metro area. Little change upstream. Would increase flood fighting downstream.

3.8.3 Formulation Criteria
The final array of alternative plans is compared using four formulation criteria established by the United States Water Resources Council in the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G). These criteria are completeness, effectiveness, efficiency and acceptability.

3.8.3.1 Completeness
The P&G defines completeness as the extent to which a given alternative plan provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects. A complete plan includes all elements necessary to function independently to achieve the planning objectives. It is an indication of the degree to which the outputs of the plan are dependent upon the actions of others or on factors beyond the control of the planners.

The no action alternative requires extensive emergency construction to prevent flood damage for all floods larger than a 10-percent chance event.

All three of the diversion channel alternatives (LPP, FCP, and ND35K) have a high likelihood of significantly reducing flood damage and flood risk, but none of the plans will eliminate flood risk. Any of the three diversion channel alternatives would substantially reduce the need for emergency floodfighting up to the 1-percent chance event on the Red River. For larger and less frequent events, diversion plans allow for additional in-town flood barriers (either permanent or temporary) to be constructed. The combination of the diversion channel and emergency flood fighting for those extremely rare events provides a very high level of risk reduction to the communities of Fargo and Moorhead.

The North Dakota diversions (LPP and ND35K) are more complete solutions to the regional flood problem, because they would reduce the risk of flooding from the major tributaries in the North Dakota portion of the study area that are not addressed by the Minnesota diversion (FCP).

The diversion channel alternatives require relatively minimal operations. Operations are necessary at the control structure on the Red River for the FCP. The LPP and ND35K plans will require operations at the Red River control structure, the Wild Rice River control structure, and closure of a structure on Wolverton Creek. The operations and maintenance of these structures and all project features will be dictated in the Operation and Maintenance manual that will be provided to the non-federal sponsors upon completion of the project.

The non-federal sponsors will be responsible for the long-term maintenance of the project along with the eventual repair, rehabilitation, and replacement of project features. Maintenance would include but not be limited to mowing and vegetation management, repair of erosion, debris removal and routine maintenance of mechanical equipment. Failure to maintain the project over the long-term could impact the completeness of the plan. It is unlikely that the non-federal sponsors would neglect the long-term maintenance requirements for any of the plans considered in the final array of alternatives.

The diversion plans are complete plans that, once constructed, would include all features necessary to produce the estimated economic benefits described in this report.

3.8.3.2 Effectiveness

The P&G defines effectiveness as a measure of the extent to which a plan achieves its objectives. All of the plans in the final array partially achieve the planning objectives.

All of the alternatives considered in the final array of alternatives meet the criteria of effectiveness to varying degrees, see Table 17. The objectives of this study as described in section 2.6 of this report and repeated here were to:

- Reduce flood risk and flood damages in the Fargo-Moorhead metropolitan area.
- Restore or improve degraded riverine and riparian habitat in and along the Red River of the North, Wild Rice River (North Dakota), Sheyenne River (North Dakota), and Buffalo River (Minnesota) in conjunction with other project features.
- Provide additional wetland habitat in conjunction with other project features.
- Provide recreational opportunities in conjunction with other project features.

Table 17 – Effectiveness in meeting planning objectives.

	No Action	LPP	FCP	ND35K
Reduce Flood Risk	No benefit	Reduces expected flood damages by 84%.	Reduces expected flood damages by 85%.	Reduces expected flood damages by 84%.
Total average annual benefits	$0	$174.8 million	$172.5 million	$173.8 million
Average annual residual damages	$194.8 million	$32 million	$30 million	$32 million
River system afforded flood risk benefits	None	Red, Wild Rice, Sheyenne, Maple, Rush and Lower Rush Rivers	Red and Wild Rice Rivers	Red, Wild Rice, Sheyenne, Maple, Rush and Lower Rush Rivers
Restore/ Improve Riverine and Riparian Habitat	None	No specific improvement to the Riverine or Riparian habitat	No specific improvement to the Riverine or Riparian habitat	No specific improvement to the Riverine or Riparian habitat
Provide additional Wetland Habitat	None	Provides additional 1450 acres of wetlands in the project area.	Provides additional 1515 acres of wetlands in the project area.	Provides additional 1527 acres of wetlands in the project area.
Provide Recreational Opportunities	None	Provides multiple recreational features including multi-purpose trails.	Provides multiple recreational features including multi-purpose trails.	Provides multiple recreational features including multi-purpose trails.

3.8.3.3 Efficiency

As defined in the P&G, efficiency is a measure of the cost-effectiveness of an alternative. Cost-effectiveness considers not only economic costs, but also other intangible costs such as environmental impacts and opportunity costs. All three of the diversion alternatives have net benefits greater than 1 and are considered to be efficient (the FCP is the most efficient). A breakdown of the net benefits and residual damages associated with each of the diversion alternatives is provided in Table 18.

Table 18 – Efficiency of plans – Net Benefits (all dollar values are in thousands)

	NO Action	LPP	FCP	ND35k
Net Benefits of Plan (NED)	$0	$74,219	$100,433	$87,565
Residual Damages	$194,800	$32,000	$30,000	$32,000

3.8.3.4 Acceptability

Acceptability is defined in the P&G as the workability and viability of the alternative plan with respect to acceptance by State and local entities and the public and compatibility with existing laws, regulations, and public policies. The LPP and FCP are in accordance with federal law and policy and would be considered acceptable for implementation; however there are differences in the level of acceptability. The ND35K plan has downstream impacts that make it unacceptable. This information is summarized in the sections below.

3.8.3.4.1 Alignment

There is a strong desire from the non-federal sponsors and the public to have the diversion plan constructed in North Dakota. A North Dakota alignment would be considered highly acceptable to the non-federal sponsors. The Minnesota alignment is also acceptable, as the non-federal sponsors and the public have indicated that doing nothing is not an option; however they generally prefer the North Dakota alignment and officially requested the North Dakota alignment as the locally preferred plan.

3.8.3.4.2 Upstream and Downstream Effects

The diversion plans would all have impacts either upstream or downstream, and public concerns have been raised regarding those effects. Analysis was conducted on the LPP, ND35K and FCP to determine the maximum extent of the impacts. Impacts from any of the diversion channel alternatives that are less than 0.05 feet are considered 0 due to the capabilities and variability of the model being used to assess the impacts. The estimated median stage increases (and decreases) are shown in Table 19 through Table 22.

Table 19 – Upstream and downstream stage impacts (10-percent chance event)

10% Chance (10-Year) Event			
Location	Stage Increase (Inches)		
	LPP	**FCP**	**ND35K**
Downstream Locations			
Emerson Gage	–	0.1	–
Pembina Gage	–	0.1	–
Drayton Gage	0.1	0.1	–
ND SH#17/MN SH317	0.2	0.1	–
Co. Hwy 15	0.1	0.1	–
Oslo Gage	0.5	0.1	–
DS Grand Forks Levees	1.0	0.2	–
Grand Forks Gage	1.3	0.2	–
LPP Maximum DS Impact Location	1.4	–	–
32nd Ave, Grand Forks	1.3	0.4	–
Thompson Gage	0.5	1.2	12.2
Hwy 25/Co.Rd 221	0.5	1.4	13.3
ND35K Maximum Impact Location	–	–	13.9
DS Sandhill River/Climax	0.4	1.6	13.6
Nielsville	0.4	1.6	12.6
DS Marsh River	0.5	1.6	11.9
US Goose River/Shelly	0.4	1.8	12.0
Halstad Gage	-1.4	1.8	7.6
Hendrum	-3.0	1.9	8.0
Perley	-6.5	2.4	11.4
Georgetown	-5.2	1.8	10.6
FCP (MN35K) Maximum Impact Location	–	2.9	–
Upstream Locations			
US FCP Diversion	–	1.6	–
US ND Wild Rice River	-61.8	-1.8	-65.2
US LPP Diversion	98.8	–	-0.6
Hickson Gage	79.0	0.5	0.6
Abercrombie	1.3	0.0	–

Table 20 – Upstream and downstream stage impacts (2-percent chance event)

2% Chance (50-Year) Event			
Location	Stage Increase (Inches)		
	LPP	**FCP**	**ND35K**
Downstream Locations			
Emerson Gage	–	0.7	–
Pembina Gage	–	1.3	–
Drayton Gage	1.0	1.2	–
ND SH#17/MN SH317	0.8	1.2	–
Co. Hwy 15	0.6	1.1	–
Oslo Gage	0.5	0.4	–
DS Grand Forks Levees	1.3	0.8	–
Grand Forks Gage	2.2	1.2	–
32nd Ave, Grand Forks	3.4	2.8	–
LPP Maximum DS Impact Location	4.6	–	–
Thompson Gage	2.9	6.7	20.9
Hwy 25/Co.Rd 221	2.5	8.8	26.9
ND35K Maximum Impact Location	–	–	29.4
DS Sandhill River/Climax	2.5	9.2	29.3
Nielsville	2.2	9.6	25.3
FCP (MN35K) Maximum Impact Location	–	9.7	–
DS Marsh River	1.9	8.5	22.2
US Goose River/Shelly	1.4	8.0	17.3
Halstad Gage	0.0	4.8	10.3
Hendrum	-1.4	4.9	15.1
Perley	-3.8	4.0	9.4
Georgetown	-2.8	3.6	8.0
Upstream Locations			
US FCP Diversion	–	-1.8	–
US ND Wild Rice River	-112.9	0.6	-112.2
US LPP Diversion	85.2	–	0.0
Hickson Gage	55.0	0.4	0.2
Abercrombie	1.7	0.1	–

Table 21 – Upstream and downstream stage impacts (1-percent chance event)

1% Chance (100-Year) Event			
Location	Stage Increase (Inches)		
	LPP	**FCP**	**ND35K**
Downstream Locations			
Emerson Gage	–	0.7	–
Pembina Gage	–	2.0	–
Drayton Gage	1.0	1.7	–
ND SH#17/MN SH317	0.8	1.6	–
Co. Hwy 15	0.6	1.8	–
Oslo Gage	0.7	1.1	–
DS Grand Forks Levees	1.8	2.5	–
Grand Forks Gage	2.9	4.1	–
LPP Maximum DS Impact Location	3.5	–	–
32nd Ave, Grand Forks	3.4	5.8	–
Thompson Gage	0.5	7.0	15.8
Hwy 25/Co.Rd 221	-0.2	10.7	23.6
ND35K Maximum Impact Location	–	–	25.4
DS Sandhill River/Climax	-0.5	11.8	25.3
FCP (MN35K) Maximum Impact Location	–	12.5	–
Nielsville	-0.5	12.4	22.8
DS Marsh River	-0.4	10.7	19.4
US Goose River/Shelly	-0.5	9.2	15.1
Halstad Gage	-0.7	6.2	10.4
Hendrum	-0.7	6.6	11.3
Perley	-3.4	6.6	7.6
Georgetown	-3.0	5.8	8.4
Upstream Locations			
US FCP Diversion	–	6.8	–
US ND Wild Rice River	-107.9	5.3	-105.1
US LPP Diversion	98.8	–	0.2
Hickson Gage	64.6	-0.1	0.1
Abercrombie	1.3	0.0	–

Table 22 – Upstream and downstream stage impacts (0.2-percent chance event)

0.2% Chance (500-Year) Event			
Location	Stage Increase (Inches)		
	LPP	**FCP**	**ND35K**
Downstream Locations			
Emerson Gage	–	1.0	–
Pembina Gage	–	2.2	–
Drayton Gage	1.3	1.0	–
ND SH#17/MN SH317	0.8	1.0	–
Co. Hwy 15	1.1	1.2	–
Oslo Gage	0.6	0.8	–
DS Grand Forks Levees	1.4	1.9	–
Grand Forks Gage	2.6	4.6	–
LPP Maximum DS Impact Location	3.2	–	–
FCP (MN35K) Maximum Impact Location	–	5.6	–
32nd Ave, Grand Forks	2.8	5.6	–
Thompson Gage	-0.6	2.4	7.2
Hwy 25/Co.Rd 221	-1.4	3.4	6.6
DS Sandhill River/Climax	-1.8	3.8	7.9
ND35K Maximum Impact Location	–	–	8.4
Nielsville	-1.9	4.4	7.7
DS Marsh River	-1.7	4.1	7.3
US Goose River/Shelly	-1.6	3.7	6.5
Halstad Gage	-2.6	1.7	3.7
Hendrum	-3.6	0.8	1.4
Perley	-4.3	-0.4	0.6
Georgetown	-4.0	-0.5	0.2
Upstream Locations			
US FCP Diversion	–	-2.3	–
US ND Wild Rice River	-15.7	2.9	-9.0
US LPP Diversion	78.0	–	1.7
Hickson Gage	34.2	-0.1	-0.4
Abercrombie	0.1	0.0	–

Downstream of the FCP diversion channel, the increase to the peak stage during a 1-percent chance event, with no emergency protection in place, is estimated to be 12.5 inches or less, depending upon location. The 1-percent chance event peak would arrive and recede about one day earlier than under existing conditions. The increase to the peak stage during a 10-percent chance event, with no emergency protection in place, is estimated to be 2.9 inches or less, depending upon location. The timing of the 10-percent chance event peak would be nearly unchanged. Upstream of the FCP diversion channel the impact would be 7.0 inches or less for a 1-percent chance event and 2.0 inches or less for a 10-percent chance event.

Downstream of the ND35K plan diversion channel, the increase to the peak stage during a 1-percent chance event, with no emergency protection in place, is estimated to be 25.4 inches or less, depending upon location. The 1-percent chance event peak would arrive and recede about 1.5 days earlier than under existing conditions. The increase to the peak stage during a 10-percent chance flood event, with no emergency protection in place, is estimated to be 13.9 inches or less, depending upon location. The 10-percent chance event peak would arrive and recede up to about one day earlier than under existing conditions immediately downstream of the diversion, but the timing at Halstad would be nearly unchanged. Upstream of the ND35K diversion channel the impact would be 0.2 inches or less for the 1-percent event and would have a benefit of 0.6 inches for the 10-percent chance event.

Downstream of the LPP diversion channel, the increase to the peak stage during a 1-percent chance event, with no emergency protection in place, is estimated to be 3.5 inches or less, depending upon location. The 1-percent chance event peak would arrive and recede about approximately the same as under existing conditions. The increase to the peak stage during a 10-percent chance flood event, with no emergency protection in place, is estimated to be 1.4 inches or less, depending upon location. The 10-percent chance event peak would arrive and recede approximately the same as under existing conditions downstream of the diversion. Upstream of the LPP diversion channel the impact would be 98.8 inches for the 1-percent event and 98.8 inches for the 10-percent chance event.

The acceptability of each plan from the standpoint of flood stage impacts depends on one's location: it would be expected that downstream interests would prefer the LPP with its minimal downstream impacts, but upstream interests would prefer either the FCP or the ND35K plan. Although the impacts of the ND35K plan were not fully modeled, the ND35K plan has large downstream impacts as far as Thompson, ND, and the impacts would likely extend into Canada because the FCP impact is 0.7 inch at Emerson, Manitoba for the 1-percent chance event, and the ND35K impacts are routinely larger than the FCP impacts. Preliminary legal analysis showed that most of the induced downstream impacts of the ND35K plan or the FCP would not rise to the level of a taking under the Fifth Amendment of the U.S. Constitution. Even though mitigation for increased stages would not be a federal requirement, the non-federal sponsors wanted to include mitigation in their desired locally preferred plan. The vast extent of the downstream impacts of the ND35K plan made it impractical to mitigate for that plan, which made the ND35K plan unacceptable to the non-federal sponsors. Although the LPP has large upstream impacts, they are in a smaller defined area that allows the sponsors to mitigate the impacts by acquiring real estate interests and employing non-structural measures effectively.

3.8.3.4.3 Tolerable level of risk

The non-federal sponsors indicated in November 2009 that a flood stage of approximately 36.0 on the Fargo gage for a 0.2-percent chance event would be tolerable because they were confident that they would be successful with flood fighting efforts up to the stage of 36.0. The analysis completed in May 2010 showed that a diversion capacity of 45,000 cfs would be required to achieve the desired stage reduction for both the Minnesota and North Dakota alignments. The information available in May 2010 showed that the 45,000 cfs alignments in both Minnesota and

North Dakota would result in a 0.2-percent chance event stage of 35.3 (see Appendix O, section 7.4.1).

The Metro Flood Study Work Group considered this information on May 13, 2010 and chose to support the ND35K plan with its associated performance rather than requesting a 45,000 cfs alternative that would have either cost significantly more or been located in Minnesota.

The LPP, FCP and ND35K alternatives all would result in a 0.2-percent chance stage of 40.0 or less, based on the Phase 3 analyses.

3.8.3.4.4 Natural Resource Impacts

Impacts to the natural resources are a concern to the public and many organizations. The North Dakota alternatives generally have more natural resource impacts than the FCP because they cross five tributaries. However, the North Dakota alignment provides flood benefits to a larger geographic area and for more people. See Chapter 5, Environmental Consequences, of this report for more detail.

3.8.3.4.5 Floodplain Impacts

Executive Order 11988 requires federal agencies to avoid direct or indirect support of floodplain development wherever there is a practicable alternative, and then to minimize impacts to the floodplain. This study has shown that a diversion channel in either Minnesota or North Dakota is the only feasible concept that will sufficiently reduce flood risk along the Red River in Fargo and Moorhead. Therefore, there is not a practicable alternative located outside the floodplain, and locating the project in the floodplain is necessary to achieve the project purpose. The primary planning objective is to reduce flood risk in the entire metropolitan area, including areas adjacent to the Wild Rice, Sheyenne, Maple, Rush and Lower Rush rivers. The LPP and ND35K plan significantly reduce flood frequency on approximately 70 and 80 square miles, respectively, currently located in the 1-percent chance event FEMA floodplain. The LPP and ND35K plan reduce flood risk from all of the rivers in the North Dakota portion of the study area. The FCP significantly reduces flood frequency on approximately 30 square miles currently located in the 1-percent chance event floodplain, but it does not address the Sheyenne River and its tributaries. Because of the different impacts on existing floodplain, the FCP alignment is more acceptable than the LPP or ND35K plan alignment to people and agencies concerned with expanding floodplain development and protection of existing floodplain function. However, as detailed in the Economics Appendix (Appendix C), the Fargo-Moorhead metropolitan area is expected to grow at a rate of 266 acres per year, regardless of whether a flood risk management project is constructed. The LPP would generally prohibit development in portions of the staging area that would have flood depths of 3 feet or greater at the 1-percent chance event, reducing impacts on the floodplain. Any floodplain impacts created by any of the possible alternatives have been minimized, and will continue to be minimized, during the design phase of the project. All three of the diversion channel alternatives (LPP, FCP or ND35K) are in compliance with Executive Order 11988 and are acceptable from that perspective.

3.8.3.5 Compliance with planning constraints

Unlike planning objectives that represent desired positive changes, planning constraints represent restrictions that should not be violated. The planning constraints identified in section 2.7 were:

- Avoid increasing peak Red River flood stages, either upstream or downstream
- Comply with the Boundary Waters Treaty of 1909 and other pertinent international agreements.
- Avoid negatively impacting the Buffalo Aquifer in Minnesota.
- Minimize loss of floodplain in accordance with Executive Order 11988, Floodplain Management

As the study developed it was acknowledged that it would not be possible to develop a large scale regional flood risk management project without causing impacts. The LPP, FCP and ND35K plan reduce flood risk for 70, 30, and 80 square miles, respectively, of highly developed or developable land. This study has shown that there are no options that could provide a high level of flood risk reduction to the region and achieve the constraint of avoiding increasing peak Red River flood stages, either upstream or downstream. Therefore this constraint was violated by each of the remaining alternatives, the LPP, FCP, and ND35K.

The LPP and FCP do not violate the three remaining constraints. The FCP was designed to avoid impacts to the Buffalo Aquifer. The ND35K has downstream impacts that would require international coordination under the Boundary Waters Treaty of 1909.

3.8.4 Trade-off Analysis

The first trade-off to be considered in evaluating the final alternative plans is to distinguish between the No Action Alternative and the other action alternatives. This is followed by the trade-off between the action alternatives.

3.8.4.1 Action versus No Action

The no action alternative does not meet any of the planning objectives. It has no positive benefits or impacts since it is the basis from which the impacts and benefits are measured. The no action alternative leaves the study area at significant and unacceptable risk from flooding. Federal involvement in future flood-fighting can be expected in the absence of a federal flood risk management project. This feasibility study has shown from a variety of perspectives that there is a federal and non-federal interest in taking action to reduce the flood risk in the study area.

3.8.4.2 Trade-Offs between Action Alternatives

The second level of trade-offs to consider is those between the action alternatives.

In comparing the size of the diversion channels, each of the diversions being considered (LPP, FCP, and ND35K) provides approximately the same amount of economic benefits. Therefore there is no tradeoff that can be made based on the economic benefits.

In comparing the location of the diversion channels, the tradeoffs are not clear cut. The North Dakota plans (LPP and ND35K) meet the completeness, effectiveness, and local acceptability criteria better than the Minnesota plan (FCP). The FCP meets the criteria of efficiency better than the LPP or ND35K plan. The FCP is also more acceptable regarding natural resources and the downstream/upstream impacts.

Cost is another consideration for trade-offs. The LPP and ND35K alternatives are more expensive than the FCP. The LPP costs more than the ND35K, due to the costs related to minimizing the downstream impacts through storage and staging. Therefore, there is a trade-off between cost and both effectiveness and acceptability. Higher cost improves effectiveness, but at some point cost becomes unacceptable.

Determination of the NED plan is tied directly to costs and economic benefits, but the determination of a locally preferred plan may take other tradeoffs into consideration. Tradeoffs related to local acceptability and cost are primarily non-federal political considerations that cannot be resolved with a technical analysis.

3.9 PLAN SELECTION

The following designations were made in the selection process:

3.9.1 NED Plan

The Corps of Engineers Planning Guidance Notebook, ER 1105-2-100 states "A plan that reasonably maximizes net national economic development benefits, consistent with the Federal objective, is to be formulated. This plan is to be identified as the NED plan." Based on the current economic analysis and information contained in Table 9 the MN40K plan is the plan that reasonably maximizes the net national economic development benefits and is therefore the NED plan.

3.9.2 ND35K Plan

The ND35K plan provides the locally desired level of benefits and follows the locally preferred alignment in North Dakota. It provides fewer total average annual benefits than the NED plan. The ND35K plan would cause stage increases downstream as described in section 3.8.3.4.

3.9.3 Locally Preferred Plan (LPP) and Selected Plan

3.9.3.1 The LPP is the plan that, in the opinion of the non-federal sponsors, best meets the needs of the local community. The LPP is a diversion channel that follows the ND35K alignment but incorporates upstream staging and storage along with a smaller-capacity channel. The revised plan provides approximately the same total average annual benefits and residual damages as both the FCP and ND35K plan.

3.9.3.2 As described in section 3.5.10, the cities of Fargo and Moorhead, Cass County, North Dakota and Clay County Minnesota jointly requested that the ND35K plan be pursued as a locally preferred plan (LPP) on March 29, 2010. The request to designate the LPP as the tentatively selected plan was approved by the Assistant Secretary of the Army for Civil Works [ASA(CW)] on April 28, 2010. The approval letter can be found in Appendix O, Plan Formulation. The request to approve the LPP (at the time the ND35K plan) as the tentatively selected plan was based on the following considerations as understood at that time:

1. The non-federal sponsors requested in writing that a LPP be pursued, and approval was obtained from the ASA(CW) to tentatively recommend the LPP.
2. The plan had net flood risk management benefits of $95,400,000 annually.
3. The plan provided average annual benefits of $171,100,000.
4. The plan provided additional benefits from multiple river systems including the Red, Wild Rice, Sheyenne, Maple, Lower Rush, and Rush Rivers.
5. The plan provided benefits to a larger area and protects a larger number of people than the NED plan.
6. It significantly reduced the expected loss of life from flooding and provided the communities with the ability to react in times of emergencies.
7. It was a more robust solution than smaller plans considering the potential for future flood flows and frequencies to be larger than reflected in the historic record.
8. It significantly reduced the risk of catastrophic damage for very large events.
9. The non-federal sponsors were prepared to pay the additional costs associated with the LPP.

3.9.3.3 A new alternative was formulated in Phase 4 that was based on the ND35K plan alignment but incorporated upstream staging and flood storage immediately upstream of the diversion channel and a reduced channel capacity. The combination of upstream staging and storage with reduced channel capacity minimized downstream impacts while providing nearly the same total average annual benefits and residual damages as the ND35K plan. The revised plan with upstream impacts became the final LPP. The cities of Fargo and Moorhead, Cass County, Clay County, the Southeast Cass Water Resource District and the Buffalo-Red River Watershed District provided a letter on April 6, 2011 endorsing the revised LPP and requesting that it be identified as the tentatively recommended plan. The ASA(CW) provided a letter dated April 28, 2011 allowing the LPP to be identified as the tentatively selected plan in the Supplemental Draft EIS.

3.9.4 Federally Comparable Plan (FCP)

The MN35K plan is the FCP. The LPP provides fewer total average annual benefits than the NED plan. Therefore, as described in section 3.6.5, it was necessary to develop a plan smaller than the NED plan that could be compared to the LPP for cost-sharing purposes. Table 9 shows that the MN35K plan would provide similar total average annual benefits and residual damages compared to the LPP. Therefore, the federal investment in the LPP should be capped at the investment that would have been made for the comparable MN35K plan. The MN35K plan is fully developed and described below for comparison with the LPP and the ND35K plan.

3.10 RISK AND UNCERTAINTY

Areas of risk and uncertainty are analyzed and described so that decisions can be made with knowledge of the degree of reliability of the estimated benefits and costs and of the effectiveness of alternative plans.

3.10.1 Climate Variability – Expert Opinion Elicitation
The hydrologic record of the Red River of the North shows a trend of increasing magnitude and frequency of flooding in recent decades. A panel of experts in hydrology and climate change was convened to elicit opinions on how to appropriately reflect this trend in the current analysis (see Appendix A, Hydrology). The panel concluded that the hydrologic record showed a "dry" period in the early decades of the twentieth century and a "wet" period in later years continuing to the present. The panel recommended using non-standard hydrologic methods, because it appears that the traditional analysis underestimates the expected frequency of flooding.

To account for the uncertainty in climate variability, revised flow frequency curves were developed in accordance with the expert panel's recommendations, and this analysis was used for the final screening to ensure that the tentatively selected plan would be able to adequately perform in the future. This analysis used the revised flow frequency curves which changed the 1-percent chance event flow to be approximately 34,700 cfs at present; 32,900 cfs in 2035; and 31,300 cfs in 2060.

3.10.2 Cost and Schedule Risk Assessment
A cost and schedule risk assessment was completed on all three alternatives. This assessment is in compliance with ECB No. 2007-17, dated September 2007 and was completed using the "Cost and Schedule Risk Analysis Guidance" dated May 17, 2009 and developed by the Directory of Expertise for Civil Works Cost Engineering (Walla Walla District). The Directory of Expertise completed the cost and schedule risk assessment with assistance from the study team and non-federal sponsors. Details of the cost and schedule risk analysis are located in Appendix N of the FEIS.

The cost and schedule risk assessment was completed for the ND35K plan prior to the May 2010 Draft EIS. The assessment identified a number of areas where future study efforts should be focused to reduce uncertainties:

For the ND35K, efforts need to be focused on:

1. Project Schedule
2. Time to plan (Feasibility)
3. Unplanned work – additional project features
4. Natural Resources Issues
5. Number of Construction Contracts
6. Uncertainty with Geotechnical Conditions
7. Variation in estimated quantities
8. Environmental Mitigation
9. Control and Diversion of water during construction
10. Potential fluctuation in labor costs
11. Uncertainty with funding stream – Federal and Local

The cost and schedule risk assessment for the LPP was completed during Phase 4 of the feasibility study after release of the SDEIS. The Phase 4 analysis refined the analyses completed prior to May 2010 and made use of the additional information generated by the feasibility study investigations. The most likely project cost (at the October 2011 price level) is estimated at approximately $1.387 Billion. Based on the results of the analysis, the Cost Engineering Directory of Expertise for Civil Works (Walla Walla District) recommends a contingency value of $367 Million, or 26 percent. This contingency includes $279 Million (20 percent) for cost growth potential due to risk analyzed in the base cost estimate and $88 Million (6 percent) for cost growth potential due to risk analyzed in the baseline schedule. The key cost risk drivers identified through sensitivity analysis were Lawsuit Risk from NGOs and Upstream Interests, potential Scope Changes, and potential Contract Modifications, which together contribute 65 percent of the statistical cost variance. The key schedule risk driver identified through sensitivity analysis was Uncertainty with Funding Stream, which contributes 82 percent of the statistical schedule variance. This covers the risk that delay in obtaining necessary funding increments may significantly delay the project.

The cost and schedule risk assessment for the FCP was completed during Phase 4 of the feasibility study after release of the SDEIS. The Phase 4 analysis refined the analyses completed prior to May 2010 and made use of the additional information generated by the feasibility study investigations. The most likely project cost (at the October 2011 price level) is estimated at approximately $949 Million. Based on the results of the analysis, the Cost Engineering Directory of Expertise for Civil Works (Walla Walla District) recommends a contingency value of $245 Million, or 26 percent. This contingency includes $181 Million (19 percent) for cost growth potential due to risk analyzed in the base cost estimate and $65 Million (7 percent) for cost growth potential due to risk analyzed in the baseline schedule. The key cost risk drivers identified through sensitivity analysis were Scope Changes, Contract Modifications, and Undefined Acquisition Strategy, which together contribute over 56 percent of the statistical cost variance. The key schedule risk drivers identified through sensitivity analysis were Uncertainty with Funding Stream, and Political Factors, which together contribute over 78 percent of the statistical schedule variance. Uncertainty with Funding Stream covers the risk that delay in obtaining necessary funding increments may significantly delay the project. Political Factors include the risk that political factors could change project support and scope, delaying the overall project implementation.

Recommendations to address cost and schedule risk for all plans include the implementation of cost and schedule contingencies, further iterative study of risks throughout the project life-cycle, potential mitigation throughout the design phase, and proactive monitoring and control of risk identified in this study.

3.10.3 Flood Fights and Emergency Levees

As described in the In Progress Review Memorandum for Record dated June 23, 2009, included in Appendix O - Plan Formulation, the economic analysis will not give credit to the emergency flood fighting efforts. However, it is acknowledged that the probability of long-term success with an emergency flood fight is not zero but is very low. To account for this, a sensitivity analysis was completed to determine how successful flood fights could impact the project benefits. To accomplish this task, various increments of probable failure were assigned to the flood fight. This information was included in the economic model (HEC-FDA) and additional runs were performed. It was determined that a flood fight success rate of 70% or greater would be required to make the NED plan not feasible. A success rate of 30% would be required to make the ND35K plan not feasible. The results of this are based on the hydraulic model calibrated to the 2006 event and Phase 2 hydrology, as described in Appendix A, hydrology. Although the sensitivity analysis was not refined using Phase 3 or Phase 4 hydrology, the newer information would likely make flood fight success less significant for feasibility.

3.10.4 Risk of Project Failure

The project will be designed using appropriate measures and factors of safety to ensure that the constructed system is robust and resilient. However, there will be a residual risk of a component failure or exceedance of the system's design capacity. The LPP includes an emergency spillway section as part of the County Road 17 tie-back levee that would allow floods in excess of the 0.2-percent chance event to flow to the west and north around the protected area. Neither the ND35K plan nor the FCP include a similar ability to redirect extreme events. In the case of a flood event that exceeded the design capacity of the system, the tie-back levees of the ND35K plan and FCP could be overtopped, allowing a sudden influx of flood waters within the protected area. An overtopping or breach of a tie-back levee, storage area levee, or failure of a control structure in any of the alternatives could allow flood water into the protected area during any flood event in which the failure occurred. The effects of such a failure could be catastrophic, depending on the magnitude and timing of the stage increases within the protected area. A loss of life analysis was completed for the LPP to determine the impacts if a catastrophic failure were to occur. This analysis is included in Appendix D, Other Social Effects. The results of this analysis indicated that if there was a catastrophic failure with a 1-percent chance event, 31 people could lose their lives and for an event twice as large as a 0.2-percent chance event (500-year times two) the loss of life could be up to 350 individuals.

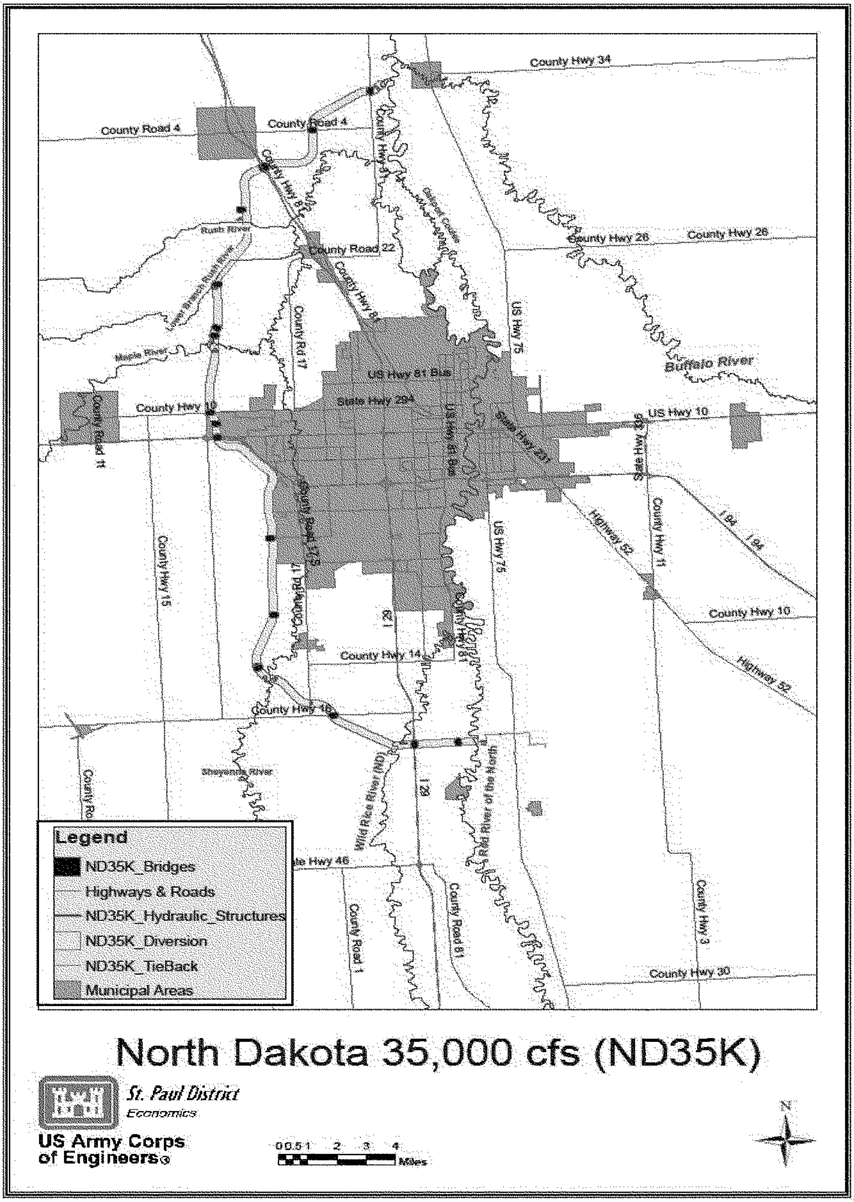
The LPP and ND35K plans both include control structures on the Red and Wild Rice rivers and aqueduct structures on the Sheyenne and Maple rivers that could be affected by ice or debris during a flood event. These structures include features to deal with ice and debris within the diversion channel and the natural river channels, but there will remain a risk that these structures could be partially blocked by ice or debris which could raise water surfaces upstream of the structures. Research on ice effects associated with the project is being conducted by U.S. Army Cold Regions Research and Engineering Laboratory (CRREL). Although the research is not completed yet, preliminary results show that for period of record, using the unified degree-day method (UDDM), 38 ice-outs occurred before the peak water stage, while 28 occurred after. For the known flood years of 2001, 2009 and 2010, UDDM predicted ice-out at Fargo before the time of peak water stage is in agreement with observations. The UDDM results do agree with the observations that, for many years, particularly ones with floods, ice-out occurs before or during the peak stage event. Addition research and modeling will be addressed through study efforts during the design and implementation phase. The effort includes study of ice at the gated structures, ice in the diversion channel, and the effect of lower flows on ice in the benefited area. The effort also includes the study of similar flood risk management projects under ice conditions (e.g. Winnipeg diversion).

It is assumed that during floods larger than the 1-percent chance event, the non-federal sponsors would augment the LPP, FCP and ND35K plans using existing flood damage reduction projects and emergency measures within the protected area. If these measures failed during a flood event, damages could be significant, although the damage would be far less than without the diversion project. (Note that the economic analyses presented in this report give no credit to emergency measures, either in the future without project condition or the with-project condition.)

3.11 DESCRIPTION OF THE ND35K PLAN

The North Dakota 35K diversion alternative was identified in the May 2010 DEIS as the LPP and the tentatively selected plan. As described in section 3.6.7.2, hydraulic modeling completed in August 2010 revealed that the ND35K plan caused far more extensive downstream impacts than had been anticipated; that information led to the development of the revised LPP described in section 3.13 below. The following description of the ND35K plan is provided as a reference only, since the plan is not supported by either the Corps or the non-federal sponsors. Figure 36 displays location of this alternative.

Figure 36- ND35K Diversion Alignment & Features



3.11.1 Plan Components (including mitigation)

Overview and list of major components:

- Diversion channel and associated structures
- Environmental mitigation
- Recreation features

3.11.1.1 Diversion channel and associated structures

The North Dakota East diversion alignment starts approximately four miles south of the confluence of the Red and Wild Rice Rivers and extends west and north around the cities of Horace, Fargo, West Fargo, and Harwood and ultimately re-enters the Red River north of the confluence of the Red and Sheyenne Rivers near the city of Georgetown, MN. Along the 36 mile path it crosses the Wile Rice, Sheyenne, Maple, Lower Rush, and Rush rivers and incorporates the existing Horace to West Fargo Sheyenne River diversion channel. The alignment of the diversion channel was modified slightly from the North Dakota alignment detailed in the DEIS in response to comments; it was adjusted northwest of Harwood, ND to avoid Drain 13.

The plan includes a large control structure on the Red River and a similar structure on the Wild Rice River. The Red River control structure would be an operable structure with three tainter gates 40 feet wide and 30 feet high. The Wild Rice River control structure would be conceptually the same as the Red River control structure, except that the Wild Rice structure would have only two gates 30 feet wide and 20 feet high. The gates on both structures would normally be fully open, and the structure would not impede flow more than a typical highway bridge. When the flow at the Fargo gage is forecasted to exceed 9,600 cfs, the gates would be lowered to restrict flow in the natural channels and redirect some of the flow over the diversion inlet weir and into the diversion channel. The lowest two feet of each gate bay would remain open even when the gates were closed to allow flow into the natural channel under all conditions.

The Red River control structure is designed with consideration for fish passage during most conditions. The bottom of the structure would be constructed to simulate natural roughness. The openings would be sized to maintain passable flow velocities until the gates were put into operation. After the gates were closed, smaller openings through the structure would direct some water into a system of fish passage channels. Under the ND35K, these would continue to allow fish passage during flood events up to approximately 30,000 cfs at Fargo.

Hydraulic structures are necessary at the points where the diversion channel crosses the Sheyenne, Maple, Lower Rush, and Rush Rivers. The tributary crossing structure systems limit the amount of water that can pass over the diversion channel with the rest of the water being diverted into the diversion channel. This results in additional flood risk reduction benefits adjacent to the tributaries downstream of the intersection. The Rush and Lower Rush Rivers, which currently consist of constructed trapezoidal channels, would be allowed to flow into the diversion channel, resulting in abandonment of the downstream portion of these rivers. The structures at the junction of the Rush and Lower Rush Rivers and the diversion channel are also designed to allow fish passage from the diversion channel into the upstream tributary channels during most flow conditions.

The hydraulic structure systems proposed on the Sheyenne and Maple Rivers would allow a minimum of a 50-percent chance event flow to continue down the rivers while diverting excess water during flood events to the diversion channel. The Sheyenne and Maple River structures would maintain fish passage to those rivers most of the time, except possibly for events larger than the 1-percent chance event. The two crossing structure systems are similar in concept; each includes a drop structure to prevent headcutting on the tributary, a spillway and channel to control diversion of tributary flows, and a hydraulic structure to pass a limited flow over the diversion channel to maintain the desired flow in the tributary beyond the diversion channel. The primary difference between the Sheyenne system and the Maple system is the presence of gated openings on the Maple system's hydraulic structure. The gates are necessary because the structure is designed to allow flows in the diversion channel to overtop the Maple River crossing structure. The gates would operate to prevent excessive flows from passing into the Maple River during extreme flood events.

The channel bottom width between the Red and Wild Rice Rivers is 300 feet. The channel bottom width is 100 feet between the Wild Rice and Sheyenne Rivers and 125 feet between the Sheyenne River and the downstream end of the diversion. Side slopes on the excavation are 1V on 10H up to a 10 foot high 50 foot wide bench then 1V on 7H to the top of the channel.

Soil excavated to construct the channel would be piled adjacent to the channel to a maximum height of 15 feet. The soil disposal piles would be as wide as necessary to contain the excavated material. The spoil slopes are 1V on 7H and 1V on 10H for the diversion side and outside slopes respectively. Portions of the soil disposal piles would be constructed to serve as levees when the water surface in the channel is higher than the natural grade. The total footprint of the plan has a maximum width of approximately 2,450 feet including areas for spoil piles. The affected acreage is approximately 6,560 acres. Efforts would be made to allow farming to continue on certain portions of the disposal areas, which could be accomplished by placing topsoil on the spoil piles.

The tie-back levee associated with this alternative connects the Red River control structure to high ground approximately 2.5 miles to the east and prevents flood water from flowing over land to the north and east into the protected area. The typical section for the tie-back levee has a top width of ten feet and side slopes of 1V on 4H. The tie-back levee would be constructed of impervious fill obtained from the channel excavation and covered with topsoil and turf. A small control structure consisting of two 10-foot by 10-foot gated box culverts would be used where Wolverton Creek crosses the Minnesota tie-back levee. The structure would normally be open to allow the creek to pass through the levee, but during floods the structure would be closed to prevent flood flows from passing.

A number of side ditch inlet drop structures would be included where the diversion crosses existing agricultural and highway drainage ditches. These structures would allow drainage to enter the channel and prevent water in the diversion channel from escaping to adjacent areas during high flow events.

The existing Horace to West Fargo diversion channel would be unnecessary and would be abandoned. The West Fargo diversion would not be altered; however, it would no longer receive large flows due to the presence of the ND35K diversion. The ND35K diversion would provide significantly greater level of risk reduction from flooding from the Sheyenne River.

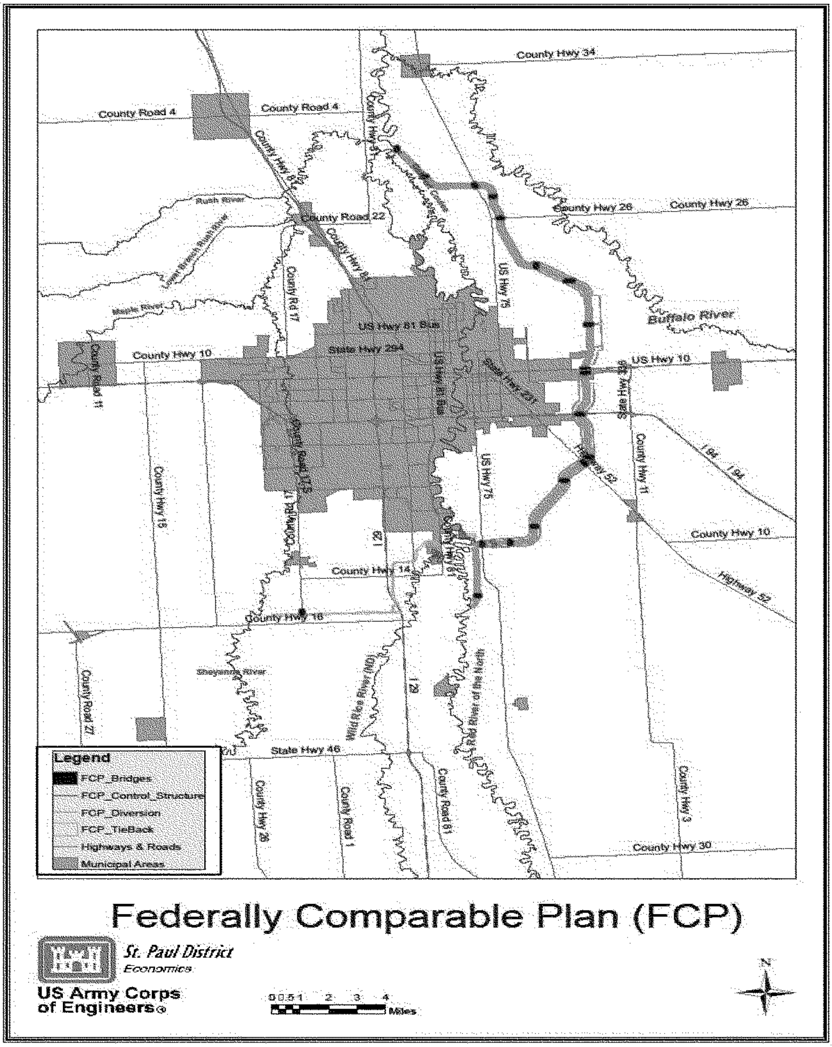
3.11.1.2 Non-structural features
There would be no non-structural measures included in the ND35K plan.

3.11.1.3 Environmental mitigation
Mitigation actions for footprint impacts were based on the concept of replacing the value of the habitat lost with an equal or greater value of restored or improved habitat value. For geomorphic impacts, the proposed mitigation would target to improve other habitat or geomorphic functions along the same length of stream for which an impact was identified. Lastly, for impacts related to connectivity and fish passage, best professional judgment was used to further implement measures that would reduce impacts to fish connectivity to levels that were less than significant. Section 5.5 of this report contains a detailed analysis of the mitigation measures.

3.11.1.4 Recreation features
No specific recreation plan was developed for the ND35K plan, but recreation features would likely be similar to those described for the LPP in section 3.13.1.4 below.

3.12 DESCRIPTION OF THE MN35K PLAN (FEDERALLY COMPARABLE PLAN)
The MN35K plan is the federally comparable plan (FCP) to be compared to the locally preferred plan for purposes of cost sharing, as discussed in section 3.9.4. Figure 37 displays the location of this alternative.

Figure 37 - FCP Diversion Alignment & Features



3.12.1 Plan Components (including mitigation)

Overview and list of major components:

- Diversion channel and associated structures
- Non-structural features
- Environmental mitigation
- Recreational features

3.12.2 Diversion channel and associated structures

The Minnesota 35K short diversion alignment starts just north of the confluence of the Red and Wild Rice Rivers and extends a total of 25 miles east and north around the cities of Moorhead and Dilworth, ultimately re-entering the Red River near the confluence of the Red and Sheyenne Rivers.

The plan includes a large control structure on the Red River which is an operable structure with three tainter gates 50 feet wide and 47 feet high. The gates would normally be fully open, and the structure would not impede flow more than a typical highway bridge up to about a 9,600 cfs flow event (approximately a 28-percent chance event) when the structure would be put into operation. Once upstream stages rose to an elevation of 898.3 feet (NAVD 1988), flows would begin to go over the diversion inlet weir. The weir would be constructed of sheetpile and rock.

The Red River control structure is designed with consideration for fish passage during most conditions. The bottom of the structure would be constructed to simulate natural roughness. The openings would be sized to maintain passable flow velocities until the gates were put into operation. After the gates were closed, smaller openings through the structure would direct some water into a system of fish passage channels. Under the FCP, these would continue to allow fish passage during flood events up to approximately 30,000 cfs at Fargo.

The diversion channel has a maximum excavation depth of 30 feet with a maximum bottom width of 400 feet. The diversion has 1V on 7H side slopes at most locations with steeper 1V on 5H slopes at the 20 highway and 4 railroad bridges. The diversion channel will require the excavation of approximately 55 million cubic yards of material. The diversion channel would be protected with rock riprap at the point that it returns to the Red River.

Soil excavated to construct the channel would be piled adjacent to the channel to a maximum height of 15 feet. The soil disposal piles would be as wide as necessary to contain the excavated material. The spoil slopes are 1V on 7H and 1V on 10H for the diversion side and outside slopes respectively. Portions of the soil disposal piles would be constructed to serve as levees when the water surface in the channel is higher than the natural grade. The total footprint of the diversion channel and soil disposal piles has a maximum width of 2,800 feet, and will affect 6,415 acres of land. Efforts would be made to allow farming to continue on certain portions of the disposal areas, which could be accomplished by placing topsoil on the spoil piles.

In addition to the diversion channel, the plan includes two smaller channels upstream of the Red River control structure to prevent stage increases upstream of the project along the Red and Wild Rice Rivers. A supplementary channel parallels the Red River upstream of the entrance to the diversion channel to allow for additional capacity to offset the breakouts to Drains 27 and 53. This secondary "Minnesota short extension channel" is approximately 3.7 miles long and has a 215 foot bottom width, with side slopes similar to the diversion channel. A second, shorter channel, the Wild Rice River breakout channel, was added near the intersection of I-29 and Cass Highway 16. This channel, which is less than one mile long and crosses under I-29, will convey water across I-29 that would have naturally broken out to Drain 27 and has a 50 foot bottom width, with side slopes similar to the diversion channel.

The plan also includes a 9.9 mile tie-back levee at the southern limits of the project. The tie-back levee connects the Red River control structure to high ground and prevents flood water from flowing over land to the north and west into the protected area. The typical section for the tie-back levee has a top width of ten feet and side slopes of 1V on 4H. The tie-back levee would be constructed of impervious fill obtained from the channel excavation and covered with topsoil and turf.

A number of side ditch inlet drop structures would be included where the diversion crosses existing agricultural and highway drainage ditches. These structures would allow drainage to enter the channel and prevent water in the diversion channel from escaping to adjacent areas during high flow events.

3.12.3 Non-structural features

The non-structural flood risk management measures recommended consist of fee acquisitions, elevation, and construction of flood walls. This includes 7 fee acquisitions, elevating the main floor on 22 structures, elevating the entire structure on 22 and construction of a flood wall around 1 critical facility, the public school in Harwood, North Dakota. The details of the proposed non-structural features are described in Appendix P – Non-Structural.

3.12.4 Environmental mitigation

Mitigation actions for impacts from the footprint of the project are based on the concept of replacing the value of the habitat lost with an equal or greater value of restored or improved habitat value. For geomorphic impacts, the proposed mitigation would target to improve other habitat or geomorphic functions along the same length of stream for which an impact was identified. Lastly, for impacts related to connectivity and fish passage, best professional judgment is used to further implement measures that would reduce impacts to fish connectivity to levels that were less than significant. Section 5.5 of this report contains a detailed analysis of the mitigation measures.

3.12.5 Recreational features

The conceptual recreation plan developed for the FCP includes one bituminous multipurpose trail loop and two aggregate multipurpose trail loops with a combined length of about 48-miles.

A thirty-mile loop of bituminous multi-purpose trails will be 10-foot wide asphalt, situated on the banks or levees of the diversion channel, and designed to be a trail system that will provide varying distances and aesthetic experiences to the users. The bituminous trail crosses the diversion channel in three locations. The crossing at 100th Ave N will be a shared-use crossing and will have a trail head with parking. The crossing at 15th Ave N will be a pedestrian bridge and will also have a trail head with parking. The last crossing is at the southern end of the bituminous trail and is located at County Hwy 52. This too will be a pedestrian bridge along with a trail head and parking.

The aggregate multi-purpose trails will be 10-foot wide compacted gravel. The north segment of trail will be an 8-mile loop from 110th Ave NW extending south to 100th Ave N. This trail will have a shared use crossing at 110th Ave NW along with car/trailer parking. The south segment of the trail will start at County Hwy 52 and will be a 10-mile loop extending south to US Highway 75 where there will be a shared use crossing along with car/trailer parking.

Along the bituminous portion of the trail, benches, trash receptacles and interpretive signage will be located approximately every mile and every 2 miles along the aggregate portion of the trail to provide the trail users information about the wildlife, history, culture and ecology of the area as well as respite. Support facilities for the trails include 3 trailheads, where restrooms, potable water, picnic facilities, interpretive kiosks and parking are proposed. Landscaping of trees and shrubs at the trail heads are also proposed along with native prairie grasses and forbs along the trail. All proposed recreation facilities will meet the guidelines for Americans with Disabilities Act (ADA) and the Architectural Barriers Act (ABA) as well as the final draft of the ADA-ABA Accessibility Guidelines for Outdoor Developed Areas.

3.13 DESCRIPTION OF THE SELECTED PLAN

The selected plan is the LPP: a 20,000 cfs North Dakota diversion channel with upstream staging and storage. Figure 38 displays location of this alternative.

3.13.1 Plan Components (including mitigation)

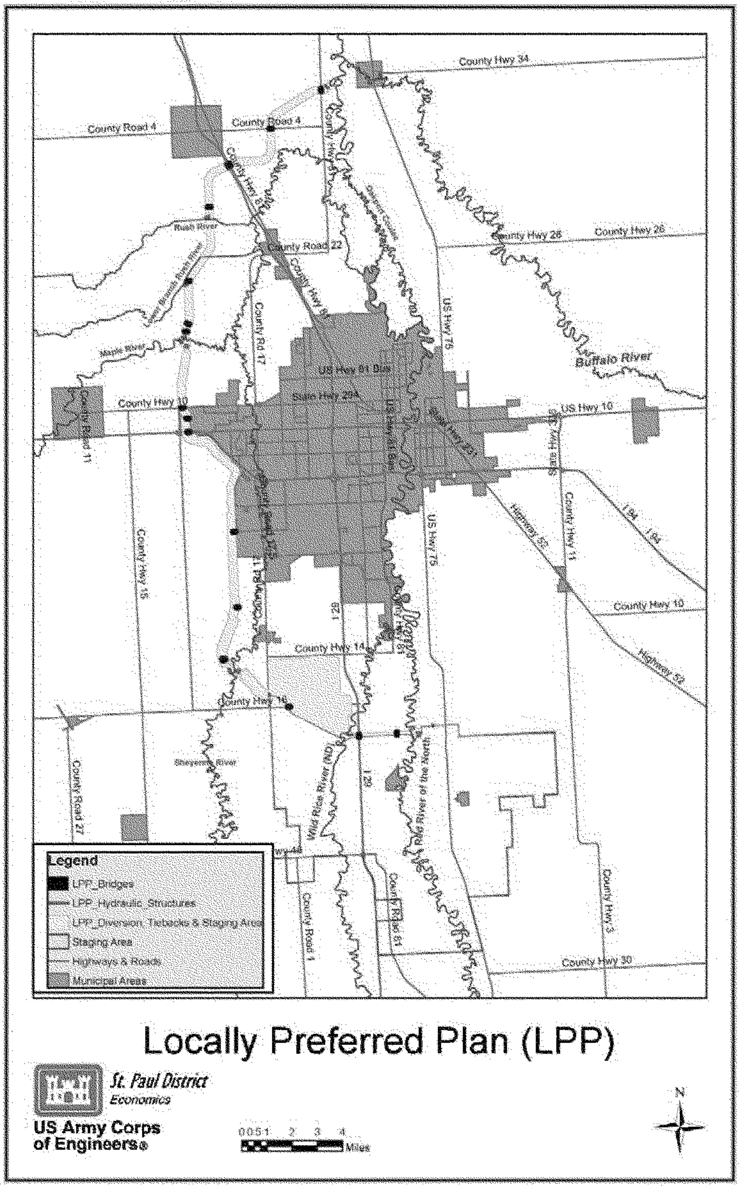
Overview and list of major components:

- Diversion channel and associated structures
- Non-structural features
- Environmental mitigation
- Recreation features

3.13.1.1 Diversion channel and associated structures

The North Dakota east diversion alignment starts approximately four miles south of the confluence of the Red and Wild Rice Rivers and extends west and north around the cities of Horace, Fargo, West Fargo and Harwood. It ultimately re-enters the Red River north of the confluence of the Red and Sheyenne Rivers near the city of Georgetown, MN. Along the 36 mile path it crosses the Wile Rice, Sheyenne, Maple, Lower Rush and Rush rivers and incorporates the existing Horace to West Fargo Sheyenne River diversion channel. The LPP alignment is identical to the ND35K.

Figure 38 - LPP Diversion Alignment & Features



The plan includes a large operable control structure on the Red River with three tainter gates 50 feet wide and 47 feet high. The gates would normally be fully open. The structure would not impede flow more than a typical highway bridge when not in operation. The structure would be operated only when the forecasted peak flow of the incoming hydrograph in the Red River of the North at the USGS gage in Fargo is greater than 9,600 cfs (approximately a 28-percent chance event). When it is operated, the control structure would limit the flow passing into the natural Red River channel through the metropolitan area and would back water up into the staging area and Storage Area 1.

The Red River control structure is designed with consideration for fish passage during most conditions. The bottom of the structure would be constructed to simulate natural roughness. The openings would be sized to maintain passable flow velocities until the gates were put into operation. After the gates were closed, smaller openings through the structure would direct some water into a system of fish passage channels. Under the LPP, with all avoid, minimize and mitigate features, fish passage would be provided under most conditions up to a discharge of approximately 30,000 cfs at Fargo.

The proposed Wild Rice River control structure, similar to the Red River control structure, would be an operable structure with two tainter gates 30 feet wide and 30 feet high. The gates would normally be fully open. The structure would not impede flow more than a typical highway bridge when not in operation. The structure would be operated only when the forecasted peak flow of the incoming hydrograph in the Red River of the North at the USGS gage in Fargo is greater than 9,600 cfs. The Wild Rice River control structure would be conceptually the same as the Red River control structure illustrated in Figure 30, except that the Wild Rice structure would have only two gates.

The diversion inlet structure is a passive weir (no gates or other regulation controls) with an effective flow width of 90 feet and a concrete spillway with a crest elevation of 903.25 feet (NAVD1988). The inlet weir is located where the diversion channel crosses Cass County Highway 17 south of Horace, ND.

Hydraulic structures, known as aqueducts, would be located where the diversion crosses the Sheyenne and Maple rivers. The Maple River structure is illustrated in Figure 33 and Figure 34; the Sheyenne River aqueduct would be similar. The aqueducts would allow for flows in the diversion to pass underneath the existing river channel, while allowing a minimum of a 50-percent chance event flow to continue down the rivers. The excess water would be diverted into the diversion channel. The 50-percent chance event flows are intended to maintain existing geomorphologic processes and existing habitat conditions in the natural channels. The Sheyenne and Maple River structures would remain biologically connected and maintain fish passage to those rivers nearly all of the time. The two crossing structure systems were similar in concept; each included a drop structure to prevent headcutting on the tributary, a spillway and channel to control diversion of tributary flows, and a hydraulic structure to pass a limited flow over the diversion channel to maintain the desired flow in the tributary beyond the diversion channel.

The structures located at the Lower Rush River and Rush River would include a combination of a vertical drop (also proposed for Drain 14), with a total width of 60 feet and 100 feet at the Lower Rush River and Rush River, respectively; and a fishway consisting of 40 feet wide riffle-pool sequences that would extend from the tributary channel down to the low flow pilot channel of the diversion channel. Both tributaries would be diverted into the diversion channel during all flow conditions, and to compensate for the loss of less than 4 miles of existing channelized tributaries, the lower 11 miles of the low flow pilot channel in the diversion channel would be constructed with meanders.

The outlet structure located where the diversion returns to the Red River of the North would be a concrete spillway with a width of 250 feet and a crest elevation of 866.0 (NAVD 1988). Fish passage features would be included at the outlet to allow connectivity between the Red, Rush and Lower Rush rivers.

The typical depth for the diversion is approximately 20 feet, with a maximum depth of 35 feet near the inlet weir. The channel bottom width between the Red and the Wild Rice rivers is 250 feet. Between the Wild Rice River and the diversion inlet weir, the bottom width is 100 feet, and downstream of the diversion inlet weir the width is 250 feet. Generally all side slopes are 1V on 7H and some slopes include benching of varying widths, see Figure 29. A low flow pilot channel would run along the bottom of this reach, and erosion protection at the toe of the main channel side slopes would be provided. Soil excavated to construct the channel would be piled adjacent to the channel to a maximum height of 15 feet. The soil disposal piles would be as wide as necessary to contain the excavated material. The spoil slopes are 1V on 7H and 1V on 10H for the diversion side and outside slopes respectively. Portions of the soil disposal piles would be constructed to serve as levees when the water surface in the channel is higher than the natural grade. The total footprint of the LPP diversion channel has a maximum width of 2,200 feet including areas for disposal piles. The affected acreage is 8,054 acres. It is anticipated that farming could continue on certain portions of the disposal areas, which could be accomplished by placing topsoil on the spoil piles.

The existing Horace to West Fargo diversion channel would be unnecessary and would be abandoned. The West Fargo diversion would not be altered; however, it would no longer receive large flows due to the presence of the LPP diversion. The LPP diversion would provide significantly greater level of risk reduction from flooding from the Sheyenne River.

The main line of flood protection at the south end of the project includes the embankments adjacent to the diversion channel, Storage Area 1 embankments, and a tie-back levee from the Red River control structure to high ground in Minnesota. A small control structure consisting of two 10-foot by 10-foot gated box culverts would be used where Wolverton Creek crosses the Minnesota tie-back levee. The structure would normally be open to allow the creek to pass through the levee, but during floods the structure would be closed to prevent flood flows from passing.

In order to nearly eliminate downstream impacts, upstream staging and storage of approximately 200,000 acre-feet immediately upstream of the diversion channel inlet would be required. Figure 32 shows the area that would be affected during a 1-percent chance flood event. The Red River and Wild Rice River control structures would be operated to raise water surface elevations to a maximum of 922.8 feet at the diversion inlet for all events up to a 0.2-percent chance event. Storage Area 1 is a 4,360-acre area on the north side of the LPP diversion channel between the Wild Rice River and the Sheyenne River, and will be formed by nearly 12 miles of embankments. Storage Area 1, combined with staging in the floodplain, will nearly eliminate impacts from the project on flood levels downstream of the diversion channel outlet. The diversion works would be operated not only based on peak flows but primarily based on total hydrograph volumes, in particular those during the rising limb of the hydrograph. A tie-back levee along Cass County Road 17 (CR17) would be needed to keep staged water from crossing overland into the Sheyenne River. The levee would include construction of a ditch to capture local and overland flows. A portion of the CR17 tieback levee would be at an elevation lower than the other tie-back levees. This portion of the levee will act as an emergency spillway for extreme events that exceed the 0.2-percent chance event design capacity of the project.

3.13.1.2 Non-structural features

The non-structural mitigation measures recommended consist of fee acquisitions, construction of ring levees and the acquisition of flowage easements. These measures are recommended within the staging and storage areas as indicated in Figure 27 and Figure 39. The staging area is defined by the red boundary and the storage area is defined by the purple boundary shown in Figure 39; this area is needed for the operation of the project and a number of mitigation features are being recommended within this area. The proposed mitigation for the area is broken into two parts, one for homes, structures, and businesses and the other for agricultural lands. Impacted homes, structures, and businesses that have greater than 3 feet of flooding for the 1-percent chance event with the project in place would be purchased, those with 1 to 3 feet of flooding would be considered for ring levees or a purchase (a risk and safety analysis will be conducted for determination of viability of a ring levee), and those with less than 1 foot of flooding would have flowage easements purchased for the property. Farmsteads in the staging or storage area will be given additional consideration based on the depth of flooding, duration of flooding, and access. Acquisition of farmsteads will generally follow the mitigation plan listed above, however under some circumstances it may be viable to construct a ring levee or raise the farmstead. In any case, where farmsteads would have greater than 3 feet of flooding a buyout would be offered to the owner prior to consideration of other options. Impacts to agricultural lands in the staging area would be mitigated through the acquisition of flowage easements. A property-by-property analysis will be conducted to ensure that the specifics of each parcel are taken into account when determining the appropriate mitigation. Alternative mitigation options will be considered when application of the general rule does not result in adequate mitigation for a particular parcel.

Areas where fee acquisitions would occur include the communities of Oxbow, Hickson, and Bakke, ND. Comstock, MN would be impacted by the project and would generally have 1 to 3 feet of flooding with the LPP in place; a ring levee would be pursued for Comstock.

The Oxbow Community Memorial Park (Nadia's Hope Playground) was partially funded through a National Park Service Land and Water Conservation Fund grant of $40,000. The grant agreement places special requirements on the City of Oxbow and the State of North Dakota if the park cannot be maintained in perpetuity in its present location. The selected plan would include appropriate action to address the requirements of the grant agreement, depending upon the actual impact to the park when the project is implemented. Details will be coordinated with the North Dakota Parks and Recreation Department during the design phase.

The non-structural mitigation approach was developed based on what the actual risk to the remaining properties would be with the LPP in place. It was determined based on information from the NRCS, local ring levee programs, and Corps experience indicating that ring levees in excess of 5 feet are not practicable given the added maintenance requirement and risk of failure attendant to levees of higher elevation. Ring levees would generally only be pursued for flooding of up to 3 feet because 2 feet of freeboard is needed to account for risk and uncertainty, for a total ring levee height of up to 5 feet. Each parcel will be analyzed for safety concerns, and if it is determined that any property owner is subject to an unacceptable safety risk, that parcel would be eligible for fee acquisition.

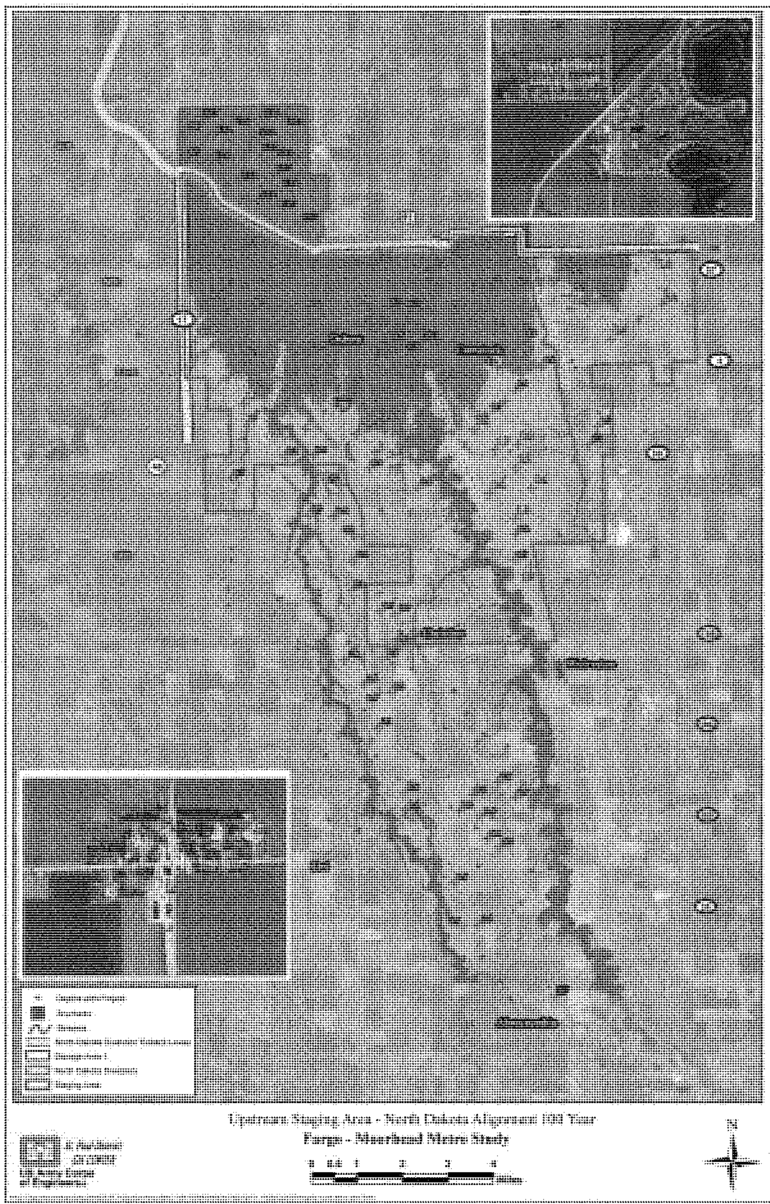
In areas with greater than 1 foot of flooding for the 1-percent chance event, no residential development will be allowed. In areas with less than 1 foot of flooding for the 1-percent chance event that are contained in the staging and storage areas (Figure 27 and Figure 38), future residential development must be raised above the 0.2-percent chance event elevation.

Flowage easements will be acquired over agricultural land within the staging area. Agricultural lands would be impacted by the project primarily in the spring and it is anticipated that in most areas farming could continue without significant impacts. There is the potential for summer impacts which could cause damage to agricultural properties and in the past 108 and years of record this would have occurred 4 times in 1975, 2005, 2007, and 2009. The largest summer flow occurred in 2007 with a flow of 13,500 cfs, in that situation only a small portion of the staging area would have been impacted by operation of the project. The summer operation plan will be revisited in during the design phase to determine if a different operating plan can be used in the summer to reduce agricultural impacts without causing additional damage to the Fargo-Moorhead communities. Local concerns have been raised regarding crop insurance within the storage and staging area and coordination has been ongoing with the USDA Risk Management Agency (RMA). The RMA has indicated that the purchase of crop insurance in these areas could still be obtained, however flood impacts resulting from the project may not be covered.

Some areas along the Red River, Wild Rice River and connected drains that are outside of the designated staging area will be affected by staging operations. Impacts outside of the designated staging area are estimated to be less than one foot of additional flood depth for a one percent chance event, and most of the impacted area would be inundated under existing conditions. A legal analysis will be conducted to determine if the impacts in these areas rise to the level of a taking under the Fifth Amendment of the U.S. Constitution. Outside of the designated staging area, landowners will be compensated appropriately for any takings.

Interstate Highway 29, U.S. Highway 75 and a BNSF railroad line would be raised within the staging area to maintain transportation during flood events. All other roadways within the staging area would be allowed to flood when project operations require staging of flood water. Utilities located in the staging area will be evaluated during the design phase. Known utilities in the staging area include, but are not limited to, electric power lines and rural water supply facilities. Utilities that cannot withstand occasional flooding will be abandoned, modified or relocated, depending on the situation in accordance with applicable regulations.

Figure 39 – Upstream Staging and Storage Areas – Mitigation Plan



3.13.1.3 Environmental mitigation

Environmental mitigation actions for impacts from the footprint of the project are based on the concept of replacing the value of the habitat lost with an equal or greater value of restored or improved habitat value. For geomorphic impacts, the proposed mitigation would aim to improve other habitat or geomorphic functions along the same length of stream for which an impact is identified. For impacts related to connectivity and fish passage, best professional judgment will be used to further implement measures that would reduce impacts to less than significant levels. Section 5.5 of this report contains a detailed analysis of the mitigation measures.

3.13.1.4 Recreation features

The conceptual recreation plan for the LPP includes one bituminous multipurpose trail loop and two aggregate multipurpose trail loops with a combined length of approximately 44-miles.

The bituminous multi-purpose trails will be 10-foot wide asphalt, situated on the banks or spoils of the diversion channel, and designed to be a trail system that will provide varying distances and aesthetic experiences to the users. The bituminous trail crosses the diversion channel in two locations. The crossing at 36th Street SE will be a shared-use crossing and will have a trail head with parking while the 44th Street SE shared-use crossing will have a trail head with car/trailer parking. Additional parking will also be at 38th Street SE.

The aggregate multipurpose trails will be 10-foot wide compacted gravel. The north segment of aggregate trail will be an approximate 6-mile loop from 28th Street SE extending south to 31stth Street SE. The trail would then continue along the east side of the diversion for approximately 5 miles to 36th Street SE. This north segment will have a pedestrian crossing at the Maple River and a shared-use crossing at 28th Street SE and 31st Street SE. It will also have car/trailer parking at 28th Street SE, car parking at 31st SE and a wildlife observation structure at the Rush River. The south segment of the trail will start at 44th Street SE and will be a 4.5-mile loop extending south to 46th Street SE where there will be a shared-use crossing. The south segment will continue for approximately 8.5 miles on the east side of the diversion until the diversion joins the Red River. Along this segment there will be a pedestrian bridge crossing for the Sheyenne River and for the Wild Rice River. There will be fishing structures adjacent the Wild Rice River as well as the Red River. These fishing structures will be rustic in nature and built into the shore protection to allow anglers access to the river. Car parking will be located at 48th Street SE and a trail head with car/trailer parking will be located at County Road 81.

Along the entire trail, benches, trash receptacles and interpretive signage will be located approximately every mile to provide the trail users information about the wildlife, history, culture and ecology of the area as well as respite. Support facilities for the trails include 3 trailheads, where restrooms, potable water, picnic facilities, interpretive kiosks and parking are proposed. Landscaping of trees and shrubs at the trail heads are also proposed along with trees, native prairie grasses and forbs along the trail. All proposed recreation facilities will meet the guidelines for Americans with Disabilities Act (ADA) and the Architectural Barriers Act (ABA) as well as the final draft of the ADA-ABA Accessibility Guidelines for Outdoor Developed Areas.

3.13.1.5 General Operation and Effects
The LPP would significantly reduce flood damages and flood risk in the Fargo-Moorhead metropolitan area, but it would not completely eliminate flood risk. The LPP will reduce flood stages on the Red River in the cities of Fargo and Moorhead and will also reduce stages on the Wild Rice, Sheyenne, Maple, Rush and Lower Rush Rivers between the Red River and the diversion channel. With the LPP in place, the stage from a 1-percent chance flood event on the Red River would be reduced from approximately 42.4 to 30.6 feet on the Fargo gage. At that level, only minimal emergency measures would be required to safely pass the 1-percent chance flood event with the LPP in place. However, floods larger than the 1-percent chance event will still require emergency flood fighting measures; with the LPP in operation, the stage for a 0.2-percent chance flood event would be approximately 40.0 feet, which is comparable to the 2009 flood event.

3.13.2 Design and Construction Considerations
Please refer to the individual engineering appendices for specific design and construction information. The project construction could occur from either the downstream (North) to the upstream (South) or from the upstream to the downstream. The construction sequencing will not alter the long-term project benefits or impacts, but depending on which option is chosen the timing of the benefits or impacts could vary. Specific information on construction sequencing will be provided to the public early in the design phase, and information on construction sequencing for either option can be found in Appendix L, Cost Engineering. The non-federal sponsors have indicated a desire to begin construction from the upstream end of the project. This would result in some flood risk management benefits being realized prior to completion of the entire project; it would also require implementation of the non-structural features, as described in Section 3.13.1.2, early in the project schedule. Construction of the project, including land acquisition, will not begin until the project is authorized and funded by Congress.

3.13.3 Real Estate Requirements
A preliminary Real Estate Plan was developed as part of this project and it can be found in Appendix G, Real Estate. The Real Estate Plan identifies the plans under consideration, the types of interest that may be needed for this project and a cost breakout for the LPP, FCP and ND35K alternatives.

Property acquisition procedures as part of a Federal project are governed primarily by Public Law 91-646, the "Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970," (Uniform Act). The Uniform Act provides important protections and assistance for people affected by Federally funded projects. This law was enacted by Congress to ensure that people whose real property is acquired, or who move as a result of projects receiving Federal funds, will be treated fairly and equitably and will receive assistance in moving from the property they occupy.

The Surface Transportation and Uniform Relocation Assistance Act of 1987, designated the U. S. Department of Transportation as the Federal Lead Agency for the Uniform Act. Duties include the development, issuance, and maintenance of the government-wide regulation, providing assistance to other Federal agencies, and reporting to Congress. This responsibility has been delegated to the Federal Highway Administration and is carried out by the Office of Real Estate Services.

The Fargo-Moorhead Project will follow the Uniform Act as administered through the U.S. Department of Transportation, Federal Highway Administration, Office of Real Estate Services.

3.13.4 Local Betterments

A betterment is defined as a difference in the construction of an element of the project that results from the application of standards that the Government determines exceed those that the Government would otherwise apply to the construction of that element. The term does not include any construction of features not included in the project as defined in the project authorization. The non-federal sponsors have not indicated that any additional betterments are desired at this time.

3.13.5 Operation, Maintenance, Repair, Rehabilitation and Replacement Considerations

The non-federal sponsors will be responsible for all operations, maintenance, repair, rehabilitation and replacement (OMRR&R) of project features. The cost share agreement between the Corps and the non-federal sponsors requires the sponsors to operate the project in accordance with the OMRR&R manual provided by the Corps. This will include annual maintenance of the diversion channel and associated structures including the Red River control structure, any additional structures required for the alternative, bridges and recreation facilities. See Appendix L, Costs for a detailed breakout of the estimated OMRR&R costs for each of the alternatives. Overall cost can be found in Table 11 and Table 12. See Section 5.5 of this report for information on monitoring plans.

3.13.6 Economic Summary

The estimated first costs and OMRR&R costs have been developed using the Corps micro-computer aided cost estimating system (MCACES). The costs are allocated between the project's purposes. These costs, along with total annual costs, annual benefits, net economic benefits and the benefits-to-cost ratios are shown on Table 23. These values are based on October 2011 price levels, an interest rate of 4.125 percent and a 50-year period of economic analysis.

Table 23 – Economic Analysis of the LPP

Estimate of Project First Costs LPP				
Account	**Item**	**Flood Risk Management**	**Recreation**	**Total**
01	Lands & Damages	278,372		278,372
02	Relocations	154,291		154,291
06	Fish and Wildlife Facilities	61,987		61,987
08	Roads, Railroads and Bridges	60,045		60,045
09	Channels & Canals	783,778		783,778
11	Levees and Floodwalls	143,435		143,435
14	Recreation Facilities		29,800	29,800
Subtotal		$ 1,481,908	$ 29,800	$1,511,708
30	Planning, Engineering and Design	179,408	4,442	183,850
31	Construction Management	83,717	2,073	85,790
Subtotal		$ 263,125	$ 6,515	$ 269,640
	Interest During Construction	296,914	791	297,705
	Total Investment Costs	**$ 2,041,947**	**$ 37,106**	**$2,079,053**
Estimate of Annual Costs				
	Annualized Project Costs	97,097	1,764	98,861
	Annual OMRR&R Cost	3,501	130	3,631
	Annual Induced Damages	-		-
	Total Annual Costs	**$ 100,598**	**$ 1,894**	**$ 102,492**
Average Annual Benefits				
	Flood Risk Management	162,800	0	162,800
	Flood Proofing Cost Savings	10,430	0	10,430
	Flood Insurance Administrative Costs	960	0	960
	Non Structural Flood Risk Benefit	627		627
	Recreation	-	5,130	5,130
	Total Annual Benefits	**$ 174,817**	**$ 5,130**	**$ 179,947**
	Net Annual Benefits	$ 74,219	$ 3,236	$ 77,455
	Benefit to Cost Ratio	1.74	2.71	1.76

All costs and benefits in thousands ($1,000)

3.13.7 Environmental Commitments

Environmental commitments incorporated into the selected plan are as follows:

- The opportunity for inter-agency partnerships to develop areas for improved habitat would be explored with the non-federal sponsors, interested federal, state and local agencies, Indian Tribes and interest groups during preparation of plans and specifications. These measures could be incorporated into the project without additional authorization.
- Future coordination on constructing the Red River control structure and tributary structures. This would be coordinated with the Resource Agency Team identified in Section 6.2.
- Future coordination on ways to reduce the frequency of operation and the project impacts would be coordinated with the Resource Agency Team identified in Section 6.2. This could include the use of in-town levees or modifications to the project operating plan. It should be noted that even if a higher flow could be passed safely through Fargo-Moorhead, it would not eliminate the need for the staging and storage areas during extreme events, but it would reduce the frequency at which those areas would be needed.
- The mitigation plan includes geomorphic assessments, physical aquatic habitat assessments and fisheries surveys on the Red, Wild Rice, Sheyenne, Maple, Rush and Lower Rush rivers to verify that project assumptions have been met over time.

3.13.8 Relationship to environmental requirements

This Environmental Impact Statement was prepared in compliance with federal environmental laws, executive orders, and policies, and with State and local laws and policies as shown below including: the Clean Air Act, as amended; the Clean Water Act as amended; the Endangered Species Act of 1973, as amended; the National Historic Preservation Act of 1966, as amended; the Land and Water Conservation Fund Act of 1965, as amended; the National Environmental Policy Act of 1969, as amended; the Fish and Wildlife Coordination Act of 1958, as amended; the Farmland Protection Policy Act; Executive Order 11990, Protection of Wetlands; Executive Order 11988, Floodplain Management; and Executive Order 12898 Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations.

Table 24 summarizes the status of project actions proposed by the Corps of Engineers in relation to applicable environmental laws and regulations.

Table 24 - Status of Project Compliance with Applicable Laws and Statutes

STATUTES OR DIRECTIVES	STATUS
Federal Statutes	
Archeological and Historic Preservation Act	Partial
Clean Air Act as amended	Full
Clean Water Act as amended	Partial
Coastal Zone Management Act	N/A
Endangered Species Act of 1973, as amended	Full

Farmland Protection Policy Act of 1984	Full
Federal Water Project Recreation Act, as amended	Full
Fish and Wildlife Coordination Act, as amended	Partial
Estuary Protection Act	N/A
Land and Water Conservation Fund Act, as amended	Full
Marine Protection, Research and Sanctuaries Act, as amended	N/A
National Environmental Policy Act of 1969, as amended	Partial
National Historic Preservation Act of 1966, as amended	Partial
Resource Conservation and Recovery Act	N/A
Full Watershed Protection and Flood Prevention Act, as amended	Full
Wild and Scenic Rivers Act, as amended	N/A
Bald and Golden Eagle Protection Act	Full
Executive Orders, Memorandums, etc.	
Floodplain Management (E.O. 11988)	Full
Full Protection of Wetlands (E.O. 11990)	Full
Full Environmental Effects Abroad of Major Federal Actions (E.O. 12114)	N/A
Analysis of Impacts on Prime and Unique Farmlands (CEQ Memorandum, 8/11/80)	Full
Protection and Enhancement of Environmental Quality (E.O. 11514, as amended by E.O. 11991)	Full
Protection and Enhancement of the Cultural Environment (E.O. 11593)	Full
Environmental Justice (E.O. 12898)	Full

3.13.9 Environmental Operating Principles

The Corps' seven Environmental Operating Principles, listed in Appendix O, Section 8.2, were followed during the entire planning process as indicated in the paragraph below.

The selected plan **strives to achieve environmental sustainability** by incorporating features to facilitate fish passage, minimize impacts to geomorphology and minimize any other environmental impacts caused by the project. The feasibility study team coordinated extensively with the appropriate environmental agencies in order to **proactively consider environmental consequences** so that appropriate measures could be included in the project design and as mitigation where necessary. The project provides an appropriate **balance and synergy among human development activities and natural systems** by reducing the risk of flooding to the largest urban area in North Dakota and western Minnesota, thereby avoiding the significant environmental and economic damage that would be caused by repeated flood fighting actions and eventual catastrophic flooding of the Fargo-Moorhead metropolitan area. The plan is consistent with all applicable laws and policies, and the Corps and its non-federal sponsors **accept corporate responsibility and accountability** for the project in accordance with those laws and policies. The study team has used **appropriate ways and means to assess cumulative impacts to the environment** through the use of engineering models, environmental surveys and coordination with natural resource agencies. The project design has evolved to address as many concerns as possible, and **appropriate mitigation** will be included to address remaining impacts. Study activities including hydrologic, hydraulic, economic, geomorphic, geotechnical, cultural resource and HTRW surveys will **increase the integrated scientific knowledge base** for the

Red River Basin. The feasibility study process included numerous public and agency meetings and a project website to interact with **individuals and groups interested in the study activities**. Through those meetings and written interactions, the study team **listened actively and respectfully** to project proponents and opponents alike in an effort to find innovative solutions to the flooding problems in the study area.

3.13.10 Campaign Plan

The four goals and underlying objectives of the Corps of Engineers campaign plan, listed in Appendix O, Section 9.3, were followed during the entire planning process as indicated in the paragraph below.

The development of the plan and the information contained in the report is an **integrated, sustainable, water resource solution** that was developed through the use of collaborative approaches to effectively address the problem of flood risk management in the Fargo-Moorhead Metropolitan area. The information was presented to the non-federal sponsors and the public through the use of clear and strategic communications with an emphasis on transparency. This resulted in a plan that would sustain the aquatic resources of the nation while providing a high flood risk management level to the citizens of the Fargo-Moorhead Metropolitan area.

3.14 IMPLEMENTATION REQUIREMENTS

3.14.1 Institutional Requirements

The schedule for project implementation assumes authorization in the proposed Water Resources Development Act (WRDA) of 2011, if enacted, or a future WRDA. After project authorization, the project would be eligible for construction funding. The project would be considered for inclusion in the President's budget based upon national priorities, magnitude of the federal commitment, economic and environmental feasibility, level of local support, willingness of the non-federal sponsors to fund their share of the project cost, and the budget constraints that may exist at the time of funding. Once Congress appropriates federal construction funds, the Corps and the non-federal sponsors would enter into a project partnership agreement (PPA). This PPA would define the federal and non-federal responsibilities for implementing, operating and maintaining the project.

The Corps would officially request that the non-federal sponsors acquire the necessary real estate immediately after the signing of the PPA. The advertisement of the construction contracts would follow the certification of the real estate. The final acceptance and transfer of the project to the non-federal sponsors would follow the delivery of an operation and maintenance (O&M) manual and as-built drawings. The estimated schedule for project implementation is shown below:

Receive project Authorization	December 2011
Received construction funds	October 2012
Initiate construction	April 2013
Complete Construction	October 2021

A detailed project schedule was developed as part of this project and is included in Appendix L.

3.14.2 Cost Apportionment

Table 26 indicates the allocation of funds between the non-federal sponsors and the federal government for the Federally Comparable Plan (FCP). Table 27 indicates the allocation of funds between the non-federal sponsors and the federal government for the LPP. The project cost share is based on the FCP and the additional costs attributed to the LPP. The federal share of the project will be limited to 65 percent of the FCP for the flood risk management features. This results in a federal cost of $783,384,000 which is 65 percent of the FCP first costs of $1,205,207,000. The non-federal sponsors are responsible for the costs of the lands, easements, relocations, rights-of-way and disposal areas (LERRDs), not to exceed 50 percent of the total project cost, and for a minimum cash contribution of five percent. The LERRDs for the FCP are anticipated to cost $207,307,000, less than the project minimum 35 percent contribution that is required. The remaining non-federal share will be a cash contribution of $214,515,000; this exceeds the minimum cash contribution meaning no additional cash is needed.

The non-federal sponsors are required to pay the increment between the FCP costs ($1,205,207,000) and the LPP costs ($1,745,033,000), which is $539,826,000. The recreation features are cost shared 50/50, resulting in federal and non-federal costs of $18,157,500 each. Table 25 identifies the incremental cost difference by line item between the FCP and LPP plans. This incremental difference is 100 percent the responsibility of the non-federal sponsors.

Table 25 – Incremental cost table FCP versus LPP, without recreation.

Account	Item	LPP	FCP	(LPP-FCP)
01	Lands & Damages	278,372	73,617	-204,755
02	Relocations	154,291	109,709	-44,582
06	Fish and Wildlife Facilities	61,987	25,053	-36,934
08	Roads, Relocations and Bridges	60,045	164,383	104,338
09	Channels & Canals	783,778	604,135	-179,643
11	Levees and Floodwalls	143,435	25,328	-118,107
30	Planning, Engineering and Design	179,408	138,397	-41,011
31	Construction Management	83,717	64,584	-19,133
	Total First Costs	**$ 1,745,033**	**$ 1,205,207**	**$ (539,826)**
	All costs in thousands ($1,000)			

Table 26 – Allocation of funds table--FCP

FCP			
Item	Federal ($)	Non-Federal ($)	Total ($)
Flood Risk Management			
Lands and Damages		73,617	73,617
Relocations	164,383	109,709	274,092
Fish and Wildlife Facilities	25,053		25,053
Channels and Canals	604,135	0	604,135
Levees and Floodwalls	25,328	0	25,328
Planning, Engineering, & Design	122,046	16,351	138,397
Construction Management	56,954	7,630	64,584
Cash Contribution	-214,515	214,515	0
Total FRM	783,385	421,822	1,205,207
Recreation			
Lands and Damages	0	0	0
Relocations	0	0	0
Recreation Facilities	25,845	0	25,845
Planning, Engineering, & Design	3,852	0	3,852
Construction Management	1,798	0	1,798
Cash Contribution	-15,747	15,747	0
Total Recreation	15,747	15,747	31,494
Total Project	799,132	437,569	1,236,701
All costs in thousands ($1,000)			

Table 27 – Allocation of funds table--LPP.

LPP			
Item	Federal ($)	Non-Federal ($)	Total ($)
Flood Risk Management			
Lands and Damages		278,372	278,372
Relocations	60,045	154,291	214,336
Fish and Wildlife Facilities	61,987		61,987
Channels and Canals	783,778	0	783,778
Levees and Floodwalls	143,435	0	143,435
Planning, Engineering, & Design	156,408	23,000	179,408
Construction Management	72,985	10,732	83,717
Cash Contribution	-495,253	495,253	0
Total FRM	783,384	961,649	1,745,033
Recreation			
Lands and Damages	0	0	0
Relocations	0	0	0
Recreation Facilities	29,800	0	29,800
Planning, Engineering, & Design	4,442	0	4,442
Construction Management	2,073	0	2,073
Cash Contribution	-18,158	18,158	0
Total Recreation	18,158	18,158	36,315
Total Project	801,542	979,806	1,781,348
All costs in thousands ($1,000)			

3.14.3 Fully Funded Cost Estimate

The fully funded estimate for the selected plan includes price escalation using Office of Management and Budget inflation factors. Project inflation factors, midpoint of construction features and fully funded costs can be found in the total project cost summary in Table 28. Project funding requirements by fiscal year are summarized in Table 29, as fully funded estimates.

Table 28 – Total Project Cost Summary (LPP)

LPP TOTAL PROJECT COST SUMMARY								
	PROJECT: Fargo Moorhead Metro Feasiblity Study							
	LOCATION: Red River of the North Basin							
						FULLY FUNDED ESTIMATE		
ACCOUNT NUMBER	FEATURE DESCRIPTION	Estimated Cost ($K)	Contigency ($K)	Contigency (%)	Total First Cost($K)	Estimated Cost ($K)	Contigency ($K)	Fully Funded plus Contigency ($K)
01	Lands & Damages	220,930	57,442	26%	278,372	238,338	61,968	300,306
02	Relocations	122,453	31,838	26%	154,291	137,126	35,653	172,779
06	Fish and Wildlife Facilities	49,196	12,791	26%	61,987	54,244	14,103	68,347
08	Roads, Relocations and Bridges	47,655	12,390	26%	60,045	51,606	13,417	65,023
09	Channels & Canals	622,046	161,732	26%	783,778	693,331	180,266	873,597
11	Levees and Floodwalls	113,837	29,598	26%	143,435	131,521	34,196	165,717
14	Recreation Facilities	23,650	6,149	26%	29,799	26,308	6,840	33,148
30	Planning, Engineering and Design	145,913	37,937	26%	183,850	175,333	45,586	220,919
31	Construction Management	68,087	17,703	26%	85,790	85,679	22,277	107,956
	Total	1,413,767	367,579	26%	1,781,346	1,593,486	414,306	2,007,792
All costs in thousands ($1,000)								

Table 29 – Fully Funded estimate by fiscal year

LPP	Fully Funded Amount Plus Contingency	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	Total Project
Federal											
E&D	$ 193,232	$ 19,000	$ 45,000	$ 40,000	$ 35,000	$ 35,000	$ 10,002	$ 4,000	$3,000	$2,230	$193,232
S&A	$ 94,426		$2,557	$6,820	$10,656	$12,105	$15,345	$15,345	$15,345	$16,253	$94,426
Construction	$ 1,107,661		$ 30,000	$ 80,000	$ 125,000	$ 142,000	$ 180,000	$ 180,000	$ 180,000	$190,661	$1,107,661
Non-Federal Cash	$ (609,237)	$ (7,000)	$ (20,000)	$ (25,000)	$ (67,000)	$ (80,000)	$ (100,000)	$ (100,000)	$ (115,000)	$ (95,237)	$ (609,237)
Federal LERRD	$ 65,023		$ 45,000	$ 10,000	$ 7,000	$ 3,023					$65,023
Recreation	$ 33,148						$ 7,000	$ 7,000	$7,000	$12,148	$33,148
											$0
Total Federal	$ 884,253	$12,000	$102,557	$111,820	$110,656	$112,128	$112,347	$106,345	$90,345	$126,055	$884,253
Non-Federal											
E&D	$ 27,687	$ 5,000	$ 5,000	$ 10,000	$7,000	$687					$27,687
S&A	$ 13,530		$3,132	$3,132	$3,132	$3,132	$1,001	$0	$0	$0	$13,530
Relocation	$ 172,779		$ 40,000	$ 40,000	$40,000	$40,000	$12,779				$172,779
Lands	$ 300,306		$ 50,000	$ 50,000	$ 50,000	$50,000	$35,000	$35,000	$25,000	$5,306	$300,306
Non-Federal Cash	$ 609,237	$ 7,000	$ 20,000	$ 25,000	$ 67,000	$ 80,000	$ 100,000	$ 100,000	$ 115,000	$ 95,237	$609,237
											$0
Total Non-Federal	$ 1,123,539	$ 12,000	$ 118,132	$ 128,132	$167,132	$173,819	$148,780	$135,000	$140,000	$100,543	$1,123,539
Total Project	$ 2,007,792	$ 24,000	$ 220,690	$ 239,952	$277,788	$285,948	$261,126	$241,345	$230,345	$226,598	$2,007,792
All costs in thousands ($1,000)											

3.14.4 Permits
As part of implementing this project, the non-federal sponsors will be required to obtain a Minnesota Department of Natural Resources protected waters permit, a water quality permit from the North Dakota Department of Health, a Sovereign Lands Permit and construction permit from the North Dakota Office of the State Engineer. In order to obtain the necessary permits from the State of Minnesota, the non-federal sponsors must complete the scoping and review process required by the Minnesota Environmental Policy Act.

A Section 401 water quality certification will be obtained from the Minnesota Pollution Control Agency and the North Dakota Department of Health.

The construction contractors will be responsible for acquiring all local licenses/permits required to comply with state and municipal laws, codes and regulations (road, borrow, construction, etc,) and for acquiring the National Pollutant Discharge Elimination System (NPDES) permit from the Minnesota Pollution Control Agency and the North Dakota Department of Health.

3.14.5 Views of non-federal sponsors and any other agencies having implementation responsibilities.
The city of Fargo and city of Moorhead have expressed the desire to implement the project and sponsor project construction in accordance with the items of local cooperation that are set forth in Chapter 8. The non-federal sponsors have completed the necessary financial self-certifications to complete the feasibility report and enter into a Design Agreement. These certifications indicate that they are financially capable of moving forward with the selected plan. Additional financial certifications will be necessary prior to beginning construction.

The non-Federal sponsors wish to perform design and construction of structural flood risk management measures that are elements of the recommended plan. Pursuant to Section 221 of the Flood Control Act of 1970 as amended, the non-Federal sponsors will be eligible to receive credit for the work, subject to a determination by the Secretary of the Army that the work is integral to the project and execution of an agreement covering the work that is executed by the Corps and the non-Federal sponsors prior to work being carried out.

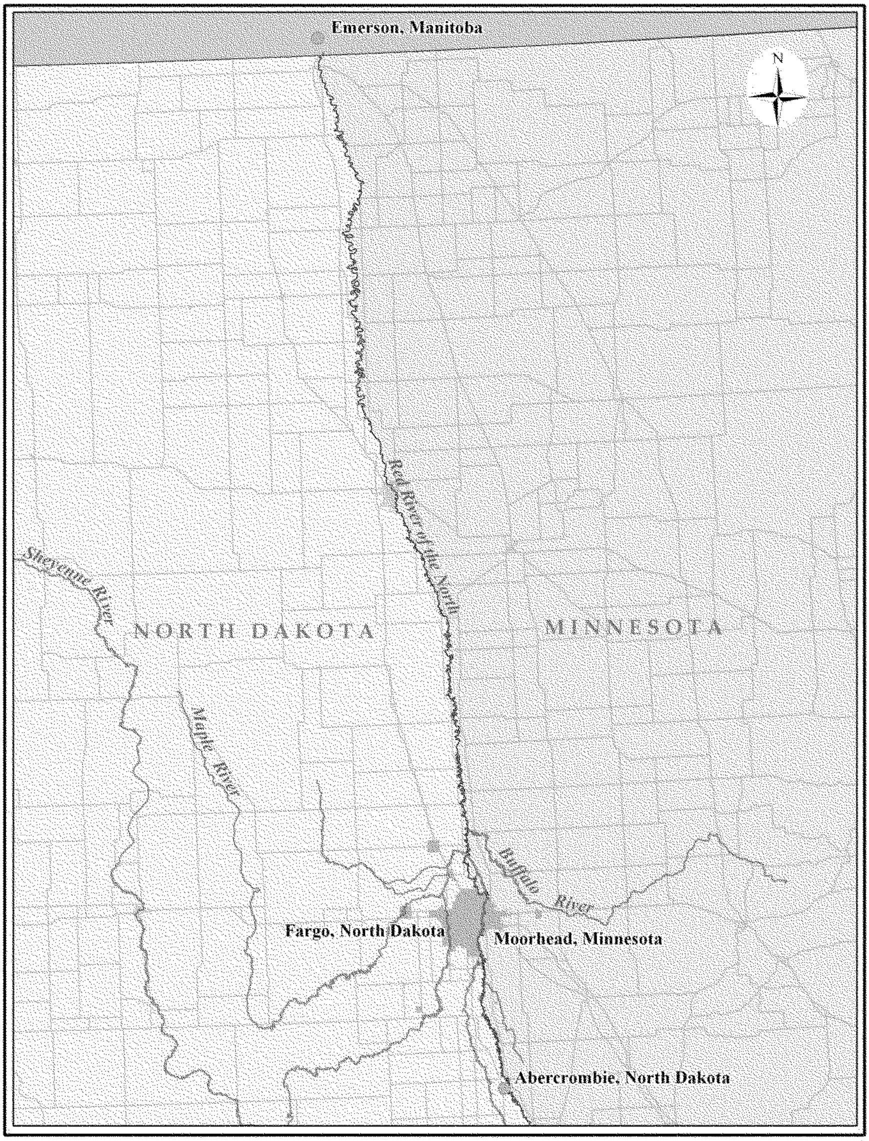
4.0 AFFECTED ENVIRONMENT

The affected environment is the area and resources that might be affected by the alternatives discussed in this report. This chapter also serves to describe the existing and future "without-project" conditions.

4.1 ENVIRONMENTAL SETTING OF THE STUDY AREA

The geographic scope of analysis for the environmental impacts of the proposed action and alternatives encompasses the Fargo-Moorhead Metropolitan region plus areas in the floodplain of the Red River from approximately 300 river miles north of Fargo near Emerson, Manitoba to approximately 30 miles south of Fargo near Abercrombie, ND. The Fargo-Moorhead Metropolitan region is located within the area from approximately 12 miles west to 5 miles east of the Red River and from 20 miles north to 20 miles south of Interstate Highway 94. This area includes the Red River and the downstream portions of the Buffalo River, Wild Rice River (North Dakota), Sheyenne River, Maple River, Rush River, Lower Rush River and other contributing streams that enter the Red River in the study area (Figure 40). In North Dakota the study area includes a portion of Cass County and the cities of Fargo, West Fargo, Hickson, Oxbow, Wild Rice, Frontier, Briarwood, Prairie Rose, Horace, Reiles Acres, and Harwood. In Minnesota the study area includes a portion of Clay County and the cities of Moorhead, Dilworth, Oakport, Rustad, Kragnes and Georgetown.

Figure 40 – Project Study Area



4.2 SIGNIFICANT RESOURCES

This section describes the existing and without project conditions for the study area. In cases where no without project condition is described it is assumed that the existing project condition will remain relatively unchanged.

Resources that could be affected by the Project's proposed alternatives occur throughout the geographic scope of the project as shown in Figure 40. Issues identified through the scoping process or resources that potentially could be affected by the Project are:

Natural Resources

- Climate
- Geomorphology
- Air Quality
- Water Quality
- Water Quantity
- Shallow Ground Water
- Aquifers
- Fisheries and Aquatic Habitat
- Riparian Habitat
- Wetlands
- Upland Habitat
- Terrestrial Wildlife
- Endangered Species
- Prime and Unique Farmland

Cultural Resources

- Historic Conditions
- Previous Cultural Resources Investigations
- Known Cultural Resources Sites
- Cemeteries

Socioeconomic Resources

4.2.1 Natural Resources

4.2.1.1 Climate

The study area is in a region classified as a subhumid to humid continental climate with cold winters and moderately warm summers. Rapid changes in daily weather patterns are common. Frequent passage of weather fronts and high and low pressure systems result in a wide variety of weather conditions. The average temperature between November and March is below 32° F, resulting in an average of 185 days per year at or below 32°F. The average temperature of the warmest month, July, is 71.1°F. The annual average normal temperature of 41.2°F reflects the northern location of the study area. On an annual basis, the prevailing wind at Fargo is from the north and northwest. The average annual precipitation in the Fargo area is about 19.5 inches. Nearly three-fourths of the annual precipitation occurs between April and September, with the remainder occurring during the winter. The average annual snowfall is about 50 inches.

The existing and future without project conditions are assumed to be the same, however an expert opinion elicitation (EOE) panel was used to determine the effects of climate change or variation. Information regarding this panel can be found in Appendix A, Hydrology.

4.2.1.2 Geomorphology
The following is summarized from a more detailed analysis of geomorphic conditions and sediment transport provided. Please reference Exhibit I of Appendix F of Attachment 5 (IF5) for a more complete description and analysis of existing geomorphic conditions.

4.2.1.2.1 Overview
The Red River of the North originates at the confluence of the Otter Tail and Bois de Sioux Rivers south of Fargo, ND. It flows northward into Canada and forms most of the boundary between Minnesota and North Dakota. The annual mean flow of the Red River at Fargo-Moorhead for the period of record (1901 to the present) averages approximately 677 cubic feet per second (cfs). Monthly median flows range from a low of about 250 cfs during the winter months, to a high of 1,300 to 1,400 cfs during April. The channel capacity of the Red River in the Fargo-Moorhead area is about 7,000 cfs.

The central feature of the Red River Basin is the Red River Valley, the flat plain that once was the bed of Glacial Lake Agassiz. The lake formed at the southern edge of the Laurentide Ice Sheet and remained in existence from approximately 11,500 to 7,500 years before present (Teller and Clayton, 1983). Within the study area and over much of the old lake bed, the lake left behind a 150 to 300 foot layer of primarily silts and clays (Klausing, 1968; Fenton et al., 1983; Tornes and Brigham, 1994) over a 50 to 60 mile wide area stretching from south of Breckenridge, MN to Winnipeg, Manitoba. This area is known as the "lake plain." Within the lake plain, topographic relief is minimal and the typical slope is less than 5 feet per mile (0.1%, IF5). The cities of Fargo and Moorhead sit at the center of the Red River Valley and the lake plain.

The lake plain is bordered by steeper beach ridges, which formed the shoreline of Glacial Lake Agassiz. Glacial rivers flowing into the lake deposited coarser sediment (sands and gravels) in these areas (Christensen, 2007), creating deltas that are mostly buried beneath later lake-deposited fine sediment. The surficial geology of the study area is shown in IF5. Regional soil survey information shows that the sandiest soils in the Red River Basin are concentrated along the shoreline areas, approximately 20 miles from the proposed LPP diversion channel.

4.2.1.2.2 General Stream Characteristics
Red River of the North
The Red River originates in the cities of Wahpeton and Breckenridge at the confluence of the Otter Tail and Bois de Sioux Rivers, approximately 187 miles upstream of Fargo and Moorhead.

Through the study area, the gradient of the Red River is extremely flat at approximately 0.6 feet per mile (0.01%).

Brooks (2003a, 2005) indicates that the suspended sediment load of the Red River is composed primarily of silt with some clay. Paakh et al. (2006) state that the fine clay and silt sediments in the Red River Valley Lake Plain are easily suspended and tend to stay in suspension even during relatively low-flow conditions. Lauer et al. (2006) hypothesize that although some of the Red River sediment moves as bedload in the form of aggregated pellets of fine sand size, most of the bed sediment is transported in disaggregated form as silt and clay in suspension. Thus over engineering time scales, unless there is a significant change in the sediment supply from the watershed, potential changes of the Red River channel geometry would be associated with channel migration rather than with bed aggradation or degradation. However, Brooks (2003b) reports a very slow net expansion of Red River (meander) bends with channel migration rates in the order of 4 centimeters per year (1.6 inches per year) over the past 1,000 years. Therefore, the Red River can be considered a stable riverine system, an opinion that is shared by Professor Gary Parker (University of Illinois, personal communication), one of the world leading experts in river morphodynamics.

There are several existing low-head dams on the Red River in the study area. Three dams in the cities of Fargo and Moorhead have been retrofitted with rock spillways to increase public safety and to improve fish passage up the Red River during low flow conditions. Two dams at Christine and Hickson, ND (just upstream of Fargo, ND) are scheduled for retrofitting, with construction potentially beginning in 2011. .

Tributaries

The Wild Rice River enters the lake plain near Wahpeton, ND and flows northward for more than 60 miles before joining the Red River approximately 10 miles south of the cities of Fargo and Moorhead. Like the Red River, the Wild Rice River is highly meandering and has a very low gradient of approximately 0.7 feet per mile (0.01%).

The Sheyenne River enters the lake plain near Kindred, ND and flows northward for approximately 75 miles before joining the Red River near Harwood. The Sheyenne River is highly meandering, with a gradient of approximately 0.8 to 1.1 feet per mile (0.01% to 0.02%) upstream of the confluence with the Maple River. The river gradient steepens somewhat near the confluence with the Maple (to about 2.8 feet per mile or 0.05%), then returns to its previous range for the rest of the distance to the Red River.

Within the study area, the Sheyenne River includes the Horace/West Fargo Diversion, which is a significant diversion project. This diversion channel routes a portion of the Sheyenne River water around Horace and areas of West Fargo during high flow conditions. Farther downstream, the West Fargo/Riverside Diversion channel routes additional flow around West Fargo and Riverside. Under the highest flow conditions all of the flow in the Sheyenne River is transferred to this diversion channel and direct flow down the main stem of the Sheyenne River is stopped entirely. The combined diversion channel rejoins the main stem of the Sheyenne River near the confluence with the Maple River.

The Maple River enters the lake plain near Leonard, ND and flows northwest for approximately 68 miles before joining the Sheyenne River near Riverside, ND. Like the other rivers, the gradient of the Maple River in the study area is extremely flat at approximately 0.7 feet per mile (0.01%).

All three tributaries have existing low-head dams within the study area, with additional dams further upstream.

4.2.1.2.3 Sediment Transport Characteristics
Historical sediment data from the USGS was reviewed for the Red River and several of its tributaries. In addition, the Corps contracted with the USGS to determine sediment concentrations, loads, and particle size distributions at six sites in the Red River and its tributaries during the spring high flow of 2010 (Blanchard et al. 2010). Sampling began on March 24, 2010 and the last measurement was taken on April 7, 2010. A second evaluation of sediment transport was also contracted with USGS during the flood of 2011, including the collection of data on the rising limb of the hydrograph. Sediment data were collected between April 4 and May 17, 2011 (44 days), with between 16 and 19 sampling events at each site. Although this second year of data is still under review, the trends in sediment transport data from 2011 appear similar to that from 2010.

Sediment transport in the Red River is dominated by the movement of suspended fine material. This suspended material is well-distributed throughout the vertical water column and is transported through the study area with minimal interaction with the stream bed. Data from 2010 also suggest the sediment load in the Red River through the cities of Fargo and Moorhead is neither increasing or decreasing. The Red River does not appear to be gaining sediment (via erosion) or losing sediment (via aggradation) over this reach. This corroborates the description of the Red River as a stable riverine system, with sediment loading from fine suspended material that is primarily washed through the system.

Similarly, observations from the Maple, Sheyenne and Wild Rice rivers suggest the sediment load carried by these tributaries in the study area is overwhelmingly fine suspended material, which is likely transported long distances from its origin in overland and bank erosion. Some of this material may settle to the bed of the river during periods of lower river velocity, but typical high flows are likely sufficient to re-suspend any settled material, leading to minimal net change in channel dimensions over time.

Specifically for the Horace/West Fargo Diversion on the Sheyenne River, data indicate that the sediment load carried by the Sheyenne River and the Horace/West Fargo Diversion is primarily fine material. The sediment load data for the diversion channel indicate that the suspended material is diverted from the main Sheyenne River in proportion to the flow diversion, and with similar timing. The diversion channel, however, carries relatively less bedload sediment, indicating that the coarser bedload material may be preferentially retained in the Sheyenne River and presumably transported into the protected areas of Horace and West Fargo.

4.2.1.2.4 Bank Stability
Bank failures are extremely common throughout rivers and streams of the Red River valley, This is largely due to soil conditions that result in poor strength of the bank. Many variables can influence bank stability. Conditions that most often trigger or exacerbate existing slides are low water during drought conditions, where water elevations are reduced to levels below those that have occurred for many previous weeks, months or even years.

The scarps from riverbank slides are typically located on the flat or gently sloped portions between the primary bank and the secondary bank. Often, the slides progress up slope, away from the river, thereby leading to a hummocky appearance between the tops of the primary and secondary banks. The slides may extend for several hundred feet along the river bank.

Slides in the Red River Valley are most typically found on the outside of river bends. These slides are likely initiated, in part, by the scouring action of the river on the toe of the primary or lower river bank. In addition to slides in the upper or secondary bank, smaller scale sloughing of the lower river bank is frequently observed.

4.2.1.3 Air Quality
The United States Environmental Protection Agency (USEPA) has established primary and secondary National Ambient Air Quality Standards (NAAQS) under the provisions of the Clean Air Act (CAA). The CAA not only established the NAAQS, but also set emission limits for certain air pollutants from specific sources, set new source performance standards based on best demonstrated technologies, and established national emissions standards for hazardous air pollutants.

The USEPA classifies the air quality within an air quality control region according to whether the region meets or exceeds Federal primary and secondary NAAQS. Primary standards define levels of air quality necessary to protect public health with an adequate margin of safety. Secondary standards define levels of air quality necessary to protect public welfare (i.e., soils, vegetation, and wildlife) from any known or anticipated adverse effects of a pollutant. Federal NAAQS are currently established for seven pollutants (known as “criteria pollutants”); including carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), lead (Pb), particulate matter equal to or less than 10 micrometers in aerodynamic diameter (PM_{10}), and very fine particulate matter ($PM_{2.5}$).

The Fargo-Moorhead area is considered a NAAQS Attainment Area for all air quality parameters (USEPA 2009). This indicates existing concentrations of air pollutants are below the established standard(s) and limited increases in emissions are allowable. Therefore, the General Conformity Rule under the CAA does not apply.

The North Dakota air quality standards are the same as those established by the USEPA, except for a more restrictive sulfur dioxide level. North Dakota’s Air Quality Program includes a Fugitive Dust Control Regulation, Chapter 33-15-17 which is primarily complaint driven (North Dakota Department of Health 2009; Bachman 2009). Cass County, North Dakota’s Dust Control Guidelines pertain to dust control on county or local roads (Cass County Highway Department

2004). Fargo has a Nuisance Ordinance that includes the generation of fugitive dust. However, no particulate values are included in the ordinance. Implementation of the ordinance is complaint driven. If complaints are received, the City works with parties involved to resolve the issue. The ordinance is interpreted more loosely for construction related dust issues (Shocker 2009).

The Minnesota air quality standards are the same as those established by the CAA, except for more restrictive levels of Sulfur Dioxide, Small Particulates and Lead. Clay County, Minnesota does not have a specific air quality regulation or fugitive dust ordinance. Fugitive dust is regulated under permits issued when doing construction/development. Fugitive dust issues are also addressed on a complaint basis. If a fugitive dust problem is identified, the County would work with the contractor to remedy the situation (Magnusson 2009)

4.2.1.4 Water Quality

Water quality in the Red River of the North main stem is generally impaired from Breckenridge, MN down to the Marsh River confluence near Shelly, MN in Norman County, a distance of approximately 191 river miles. Point and non-point sources of pollution result in high pH, fecal coliform, nutrients, biochemical oxygen demand (BOD), suspended solids, turbidity and conductivity resulting in non-support of aquatic life and overall use, and partial support of swimming, agriculture, and wildlife uses. From the Marsh River confluence downstream, the general water quality improves to threatened, with the exception of two segments, just upstream from Grand Forks, ND-East Grand Forks, MN and near Pembina, ND-St. Vincent, MN, where water quality is impaired. Cropland use, feedlots, livestock holding facilities, agricultural chemicals, urban runoff, septic systems, channelization, dredging, streambank modification, landfills, and dams contribute to oxygen depletion, eutrophication, bacterial contamination, sedimentation, toxicity from pesticides, turbidity, and habitat alteration on the Red River.

4.2.1.4.1 Red River at Fargo

Many constituent concentrations downstream of Fargo have exceeded water quality guidelines, standards and criteria. The maximum sulfate concentration of 303 mg/L was greater than the 250 mg/L EPA (2005b) secondary drinking water standard. Other exceedances, including cadmium, copper, lead, and selenium concentrations, generally occurred during the 1970s or earlier. These exceedances could be attributed to natural occurrences, pollution or sample contamination. Tornes (2005) used available data from July, 1969 to September, 1994 to obtain median values for TDS, sulfate, chloride and sodium downstream of Fargo of 356, 69, 11 and 20 mg/L, respectively. Also, a pH median value of 8.1 was identified.

Section 1.3 of Appendix F, Environmental, contains a Water Quality Spreadsheet which summarizes data provided by the Minnesota Pollution Control Agency (MPCA) load monitoring site. This site is located near Clay County Highway 26 at the Red River; about 7 miles north of Moorhead and 2 miles east of Harwood, ND. The field data were collected with an YSI multi-parameter sonde. Other samples were collected via a mid-stream mid-depth single grab with a Van Dorn type sampler and analyzed using USEPA approved lab methods.

Minnesota Pollution Control Agency classifies the reach of the Red River through the study area as Class 1C for domestic consumption; 2Bd for aquatic life and recreation; and 3C for industrial use (State of Minnesota 2009). Class 1C waters are such that with treatment consisting of coagulation, sedimentation, filtration, storage and chlorination, or other equivalent treatment processes, the treated water will meet both the primary (maximum contaminant levels) and secondary drinking water standards issued by the USEPA. Class 2Bd waters are such as to permit the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life and their habitats. These waters are suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. This class of surface waters is also protected as a source of drinking water. Class 3C waters are such as to permit their use for industrial cooling and materials transport without a high degree of treatment being necessary to avoid severe fouling, corrosion, scaling or other unsatisfactory conditions.

Future water quality in the Red River would be expected to improve slightly due to more stringent environmental laws and several ongoing initiatives in the area. The Red River Basin Commission has been working with the local soil and water conservation districts, watershed districts and Pheasants Forever on the Red River Basin Buffer initiative. Goals of this are to demonstrate a process for restoring strategically targeted riparian buffers within a small watershed so the process can be duplicated throughout the Red River Basin. This project will also demonstrate the water quality benefits to these restorations. Measurable goals include establishing buffers, restoring prescribed wetlands within the watersheds, reducing sediment concentrations/loads at stream sites, reducing total phosphorus concentrations/loads at stream sites and educating the public about benefits of buffers to promote their implementation.

4.2.1.4.2 North Dakota Tributaries

Based on the North Dakota State stream classification system the Sheyenne River is a Class IA, the Maple River and Wild Rice River are Class II, and the Rush River (upper and lower) are Class III. Class I waters are such that the quality of the waters is suitable for the propagation or protection, or both, of resident fish species and other aquatic biota and for swimming, boating and other water recreation. The quality of the waters is suitable for irrigation, stock watering and wildlife without injurious effects. After treatment consisting of coagulation, settling, filtration, chlorination, or equivalent treatment processes, the water quality would meet the bacteriological, physical and chemical requirements of the department for municipal or domestic use. Class IA are such that the quality of the waters is the same as the quality of Class I streams, except that treatment for municipal use may also require softening to meet the drinking water requirements of the North Dakota Department of Health. Class II waters are such that the quality of the waters is the same as the quality of Class I streams, except that additional treatment may be required to meet the drinking water requirements of the Department. Streams in this classification may be intermittent in nature, which would make these waters of limited value for beneficial uses such as municipal water, fish life, irrigation, bathing, or swimming. Class III waters are such that the quality of the waters is suitable for agricultural and industrial uses. Streams in this class generally have low average flows with prolonged periods of no flow. During periods of no flow, they are of limited value for recreation, and fish and aquatic biota. The quality of these waters must be maintained to protect secondary contact recreation uses (e.g., wading), fish and aquatic biota, and wildlife uses.

4.2.1.5 Water Quantity
Existing and future without project hydrologic and hydraulic conditions are discussed in Chapter 2.

The Red River is a meandering river that begins where the Otter Tail River and Bois de Sioux River join at Wahpeton, ND, and Breckenridge, MN. The Red River has 548 river miles, of which 394 are in the United States. Parts of South Dakota, North Dakota, and Minnesota are drained by the Red River.

The Red River is unusual for the northern plains because it flows northward through the center of an ancient lakebed, glacial Lake Agassiz. The remnant lakebed has extremely flat topography, a feature that characterizes the Red River Valley. The valley covers a strip of land about 35 miles wide on either side of the Red River in North Dakota and Minnesota. The Red River Valley is part of the larger Red River Basin.

The Red River receives most of its flow from its eastern tributaries because of regional patterns in precipitation, evapotranspiration, soils and topography. The Red River Valley has a sub-humid to humid climate with an average annual precipitation of about 19.5 inches. Major tributaries entering the Red River in the United States include the Sheyenne River, Red Lake River and Otter Tail River.

Most of the annual precipitation and annual evaporation occurs from April through September. As a result, most of the time precipitation is absorbed in the soil and transpired or evaporated back to the atmosphere and very little results in runoff or groundwater recharge. Most runoff is in the early spring when snowmelt and precipitation generally exceed evapotranspiration (Sloan 1972). Thus, maximum flow occurs in the spring, decreases throughout the summer and fall, and is lowest during the winter months.

Currently, there are several lowhead dams along the Red River that pool water for Municipal, Rural & Industrial (MR&I) intakes during times of low flow. A lowhead dam is a dam of low height, usually less than 15 feet, that extends from bank to bank across a stream channel. Lowhead dams are located on the river at Wahpeton, Wolverton, Hickson, Fargo, Grand Forks-East Grand Forks and Drayton, ND. Some of the dams have been modified for safety reasons and to allow fish passage (MNDNR and North Dakota Game and Fish Department 1996).

The Red River is the primary source of water for municipal, industrial, and irrigation purposes in the Red River Valley. It is the principal water supply for cities such as Moorhead, MN, and Fargo, Grand Forks, Grafton, and Drayton, ND, among others.

The Sheyenne River is a major tributary to the Red River of the North. The river begins north of McClusky, ND and meanders eastward before turning south near McVille. The southerly flow continues through Griggs and Barnes counties before turning northeast near Lisbon. The river forms Lake Ashtabula behind the Baldhill Dam north of Valley City. From Lisbon, the river crosses the Sheyenne National Grassland before entering into Cass County near the city of

Kindred. From Kindred, the river flows northeastward through the Red River Valley and into the Red River North at Fargo. The Sheyenne River flows are regulated by dams that form Lake Ashtabula and several smaller reservoirs. These dams provide flood control and can be used to supplement downstream discharge during low flow (USGS 2011).

The Wild Rice River is a tributary of the Red River; it is an approximately 240 mile long river starting as an intermittent stream near Brampton Township approximately 6 miles south of Cogswell ND. It flows eastward to Great Bend, then turns north near Wahpeton where it parallels the Red River in a winding channel approximately 5-7 miles from the Red. It flows into the Red River approximately seven miles south of Fargo.

The Maple River is a tributary of the Sheyenne River; it is an approximately 100 mile long river beginning as an intermittent stream near the town of Finley, flowing southward to Enderlin where it turns to the northeast flowing past Mapleton, flowing into the Sheyenne River approximately 5 miles north of West Fargo, not far from the confluence of the Sheyenne and Red River.

Figure 41 through Figure 44 illustrate flood inundation throughout the study area by event. Impacts to acres and existing structures are discussed in section 4.2.3 Socioeconomic Resources.

Figure 41 – 10-Percent Chance Flood – Existing Conditions

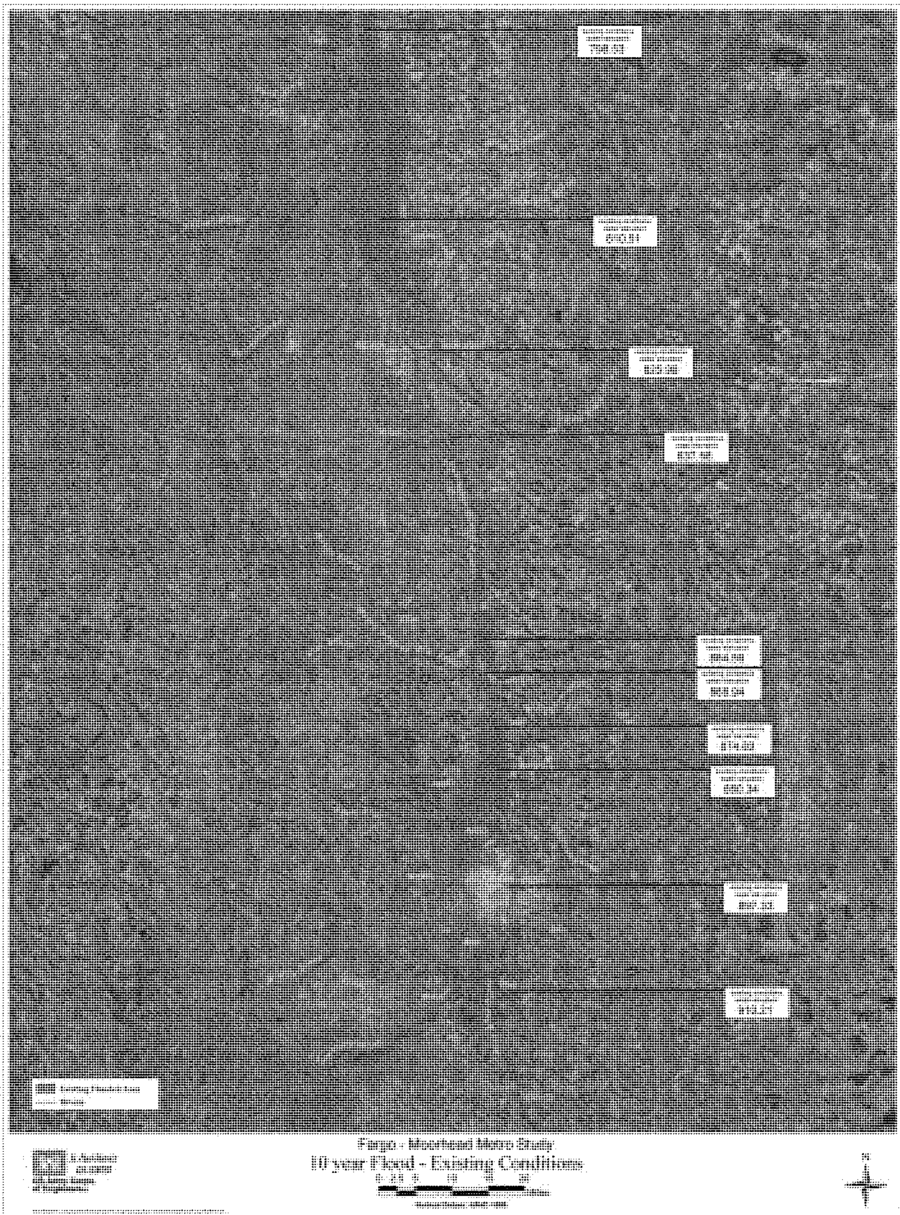


Figure 42 – 2-Percent Chance Flood – Existing Conditions

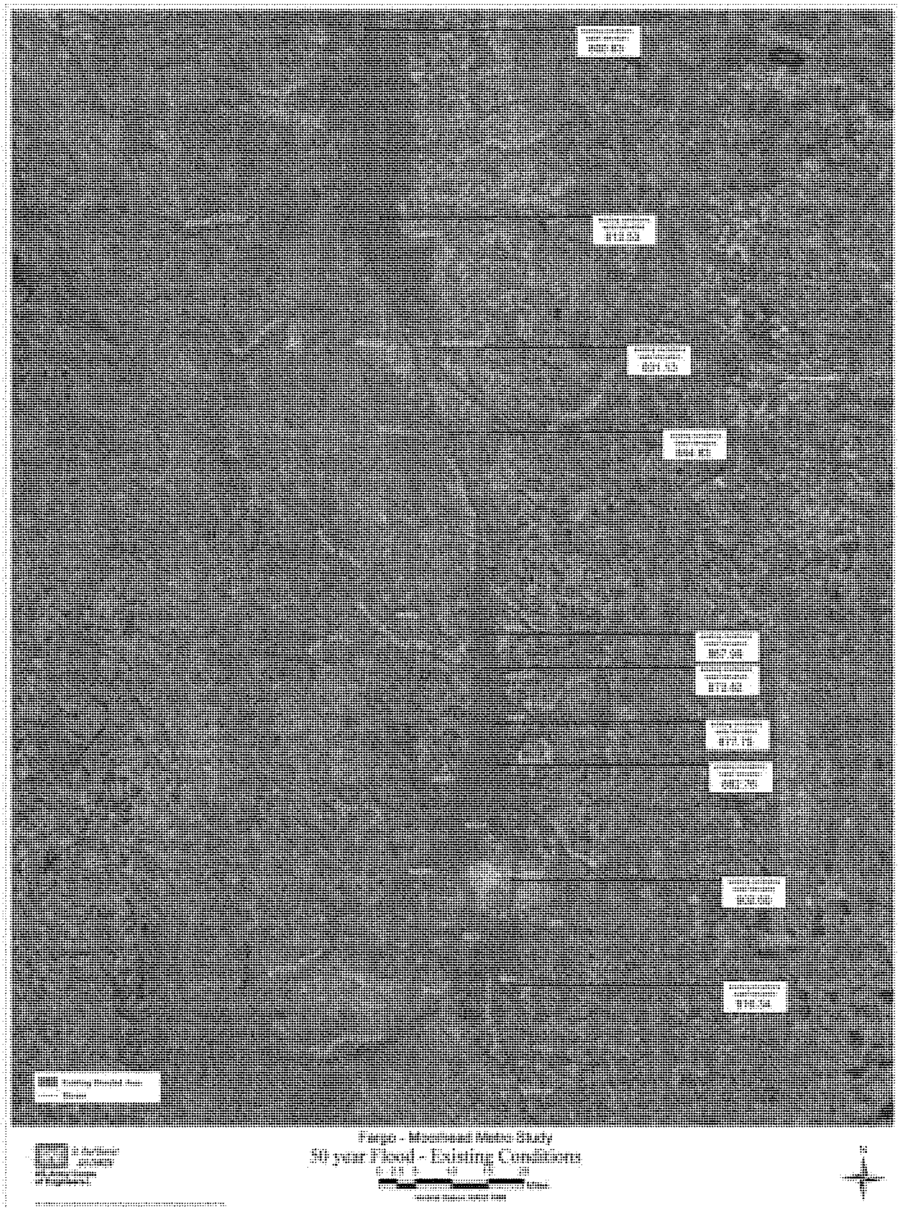


Figure 43 – 1-Percent Chance Flood – Existing Conditions

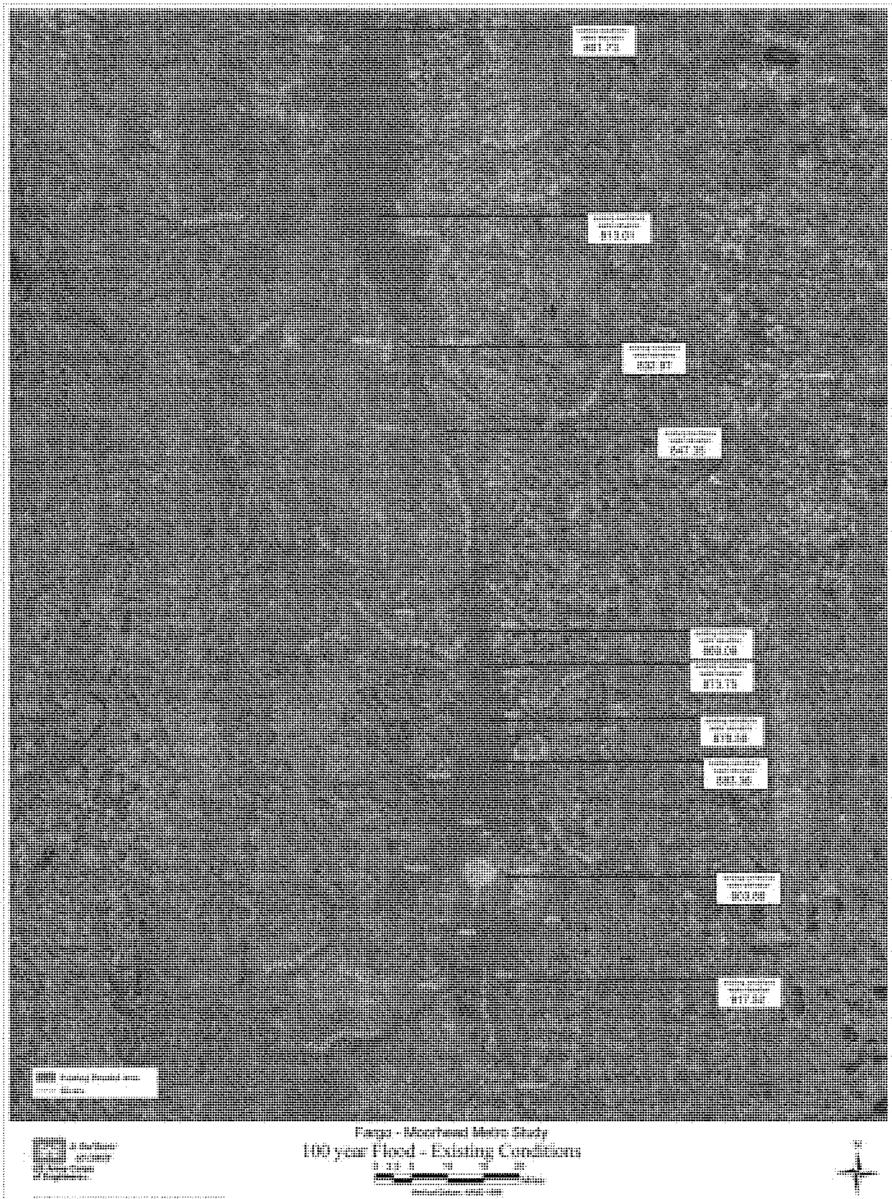
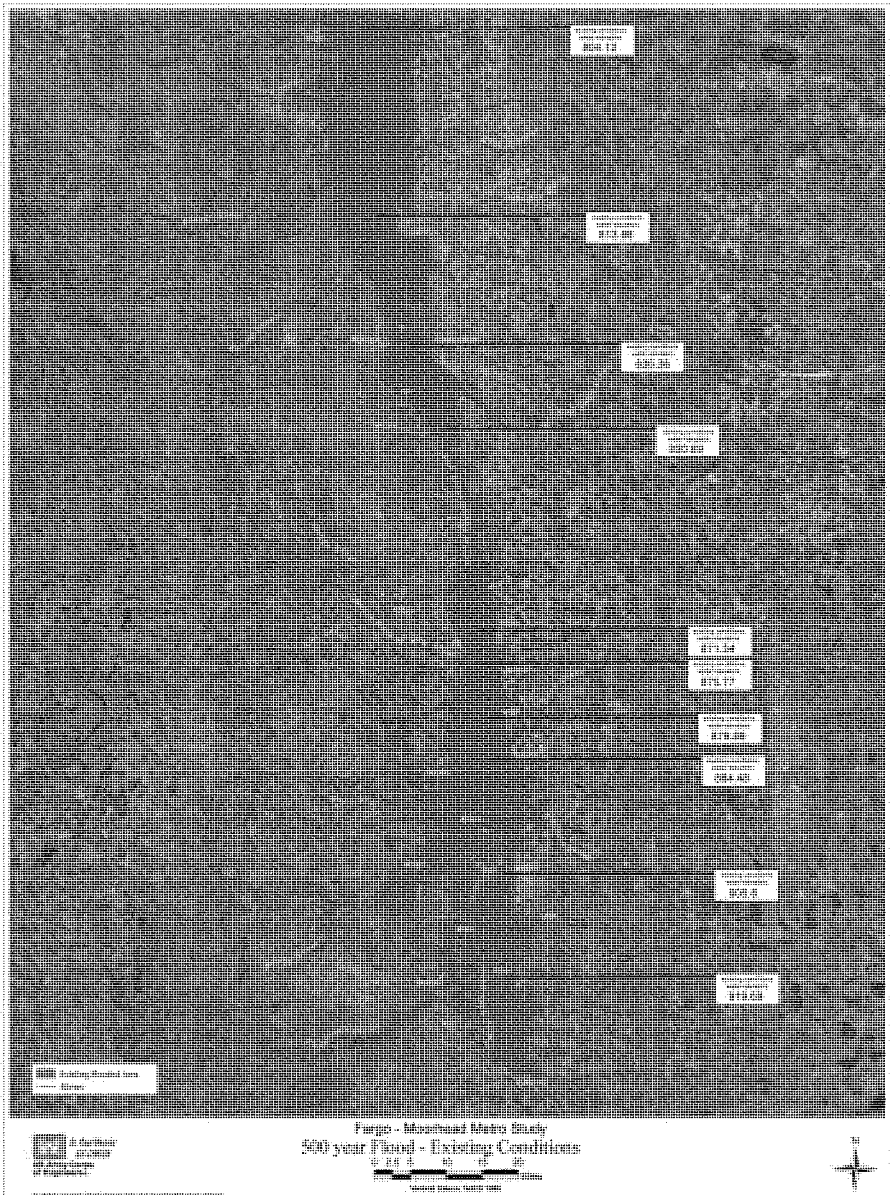


Figure 44 – 0.2-Percent Chance Flood – Existing Conditions



4.2.1.6 Shallow Ground Water

Borings have been conducted to delineate the stratigraphy, and for conducting laboratory testing of the soils necessary to define the physical parameters of the subsurface geology. Vibrating wire piezometers with automated data-loggers have been installed, straddling the proposed alignments east of Dilworth, MN (FCP) and west of Fargo, ND (ND35K and LPP). Piezometers are used to record subsurface groundwater levels, and this information is used to better understand the groundwater regime in the vicinity of the proposed diversion alignments. The piezometers are located in lower, middle and upper elevations and/or sandy layers encountered to further understand the ground water regime. Nested piezometers with data-loggers may also being placed at proposed structure locations. Once a more precise alignment is selected additional subsurface information will be needed for inclusion into the plans and specifications for project construction.

The Corps has obtained a 3-Dimensional geological model compiled by the Minnesota Geological Survey in 2005. The model used existing well and subsurface data to map the groundwater bearing deposits within the study area. The Corps is utilizing this geological data in an effort to locate potential shallow groundwater potential relative to the FCP, LPP, and ND35K diversion alignments. Additional subsurface investigations are also being used to help identify the presence, location, and limits of any smaller scale shallow ground water along the alignments.

4.2.1.7 Aquifers

For the FCP alignment the Buffalo Aquifer was identified as a planning constraint early in the feasibility study. Water usage from the aquifer has declined in recent years but is still tapped for individual, irrigation, and municipal water wells. The Buffalo Aquifer may be characterized as a north-south trending, complex, heterogeneous outwash deposit composed of primarily of sand and gravel placed during the last glacial epoch (Figure 45). Studies have shown that along its east-west boundaries the Buffalo aquifer becomes increasingly fine-grained and can include silt and clay beds. Located five to seven miles east of Moorhead, the deposit is interpreted to have been formed in a tunnel valley by glacial meltwater exiting the southern end, or snout, of a glacier. The exiting meltwater was under pressure and occurred in multiple events which are indicated by the vertical and horizontal meandering of the deposit. In Clay County the Buffalo Aquifer is 1 to 2 miles wide, and up to 250-feet thick. The top of the aquifer is at, or very near, ground surface adjacent to the Buffalo River but is buried in glacial lake clays along diversion alignments proposed to date.

The Buffalo River, located approximately 5-miles east of Moorhead, runs parallel to and along the east side of the aquifer and contributes significant recharge, especially in the northern reach of the aquifer near the city of Moorhead's north well field. Regional aquifer flow in the clayey lake plain soils adjacent is generally westward or toward the Red River of the North; variations due to local hydrology, such as over-pumping, drought conditions, and adjacent wetlands can alter local groundwater flow directions.

In 1994 the city of Moorhead opened a new water treatment plant and began taking more water from the Red River of the North. Water levels in the aquifer have risen approximately 15-feet in the succeeding 10 years. Over the last 30 years, many studies have been conducted on the Buffalo Aquifer and additional groundwater management initiatives and studies are ongoing.

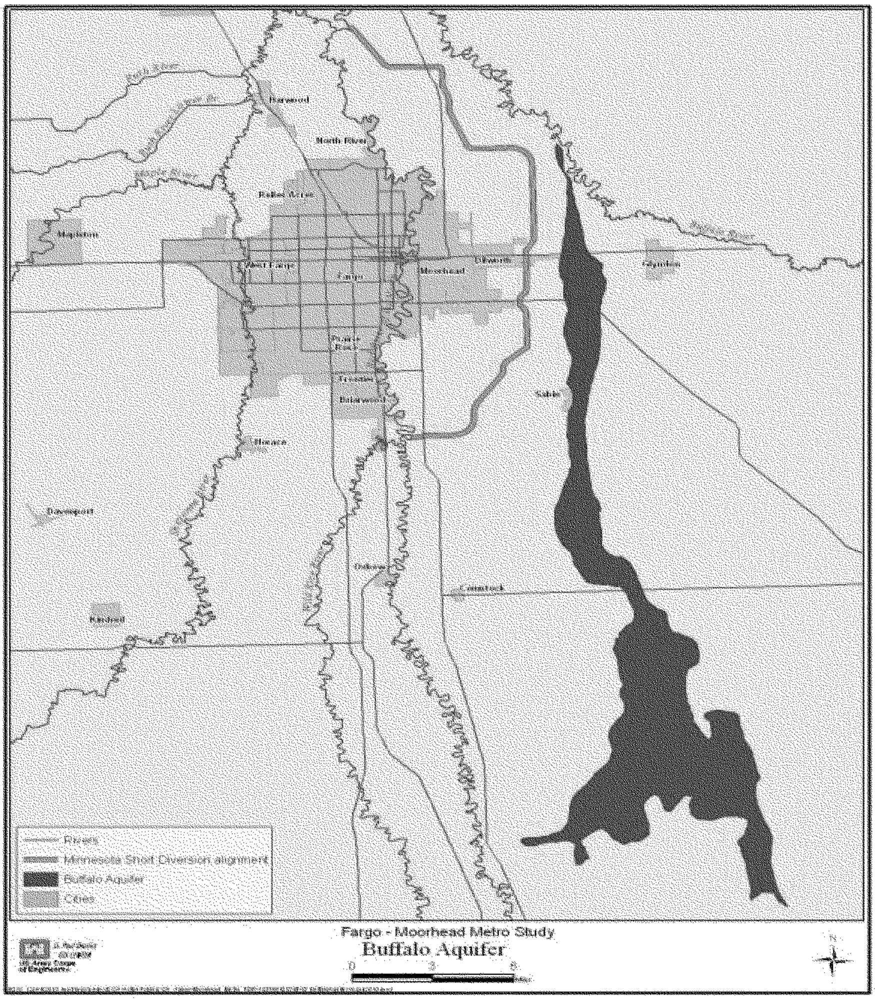
For the North Dakota alignment alternatives (LPP and ND35K) the West Fargo Aquifer is the primary water source of concern. It is possible to divide the West Fargo Aquifer into several separate sub-units but, for the purposes of this report, it shall be treated as one. Water from the aquifer is tapped for individual, irrigation, and municipal water wells. The West Fargo Aquifer is a buried glacio-fluvial deposit placed during the last glacial epoch that extends generally in a north-south direction for about 30 miles in Cass County. The modern day Sheyenne River traverses the same general trend of the West Fargo Aquifer from about 6 miles south of Horace, ND to about 2 miles south of Argusville, ND. The aquifer ranges in width from about 2 ½ to 8 miles and underlies an area of approximately 110 miles. Typically the aquifer is overlain by deposits of glacial till and glacio-lacustrine lake clay at depths of approximately 70 to 170 feet below ground surface. The aquifer is composed of material ranging in size from fine sand to boulders but is primarily fine to medium sand. In places these coarse grained deposits may be interbedded with silt or clay, especially near the top of the aquifer. The deposit is interpreted to have been formed in a tunnel valley by glacial meltwater exiting the southern end, or snout, of a glacier, in the same manner as the Buffalo aquifer.

Recharge to the West Fargo Aquifer probably occurs primarily through lateral movement of water through the till and associated deposits and by downward percolation of shallow groundwater through the glacio-lacustrine deposits. Due to the relatively tight nature of the surrounding soils it is likely that the recharge rate of the aquifer is not able to keep pace with the withdrawal rate and this is reflected in declining water levels. Regional aquifer flow appears to be influenced by areas of heavy pumping but generally the piezometric surface slopes from east to west. The average depth of the water level in the West Fargo Aquifer is not defined but it is known that the decline is such that unconfined (non-artesian) conditions now exist.

The city of West Fargo draws its municipal water supply entirely from 8 production wells located in the West Fargo Aquifer. Until alternate water sources are located it is reasonable to assume that water levels will continue to decline in the aquifer.

Other, unnamed aquifers occur at various depths within the tills and glacio-lacustrine clays adjacent to the diversion alignments. These buried aquifers may generally be characterized as elongate, discontinuous, lenses composed primarily of sand and gravel. Accurately locating and delineating these aquifers is difficult due to their scattered nature and relatively small aerial extent. On-going studies by the Corps of Engineers and others will aid in better defining these types of aquifers.

Figure 45 – Buffalo Aquifer



4.2.1.8 Fisheries and Aquatic Habitat

Areas potentially affected directly by the proposed action include the Red River of the North and adjacent tributaries around Fargo-Moorhead. These include the Wild Rice, Sheyenne, Maple, Rush and Lower Rush rivers in North Dakota, and Wolverton Creek in Minnesota. The Lower Rush is intermittent and typically does not have flow year-round, but for the purpose of this EIS will be considered one of five tributaries that could provide fisheries habitat. The project also could affect other small intermittent tributaries and drainage ditches in North Dakota. However, these likely provide limited, if any, aquatic habitat value. In Minnesota, the Buffalo River is a significant tributary located in the study area. However, the Buffalo River and other tributaries in Minnesota will not be directly impacted by the proposed action.

4.2.1.8.1 Fish Communities

The Red River is a warm water system that is dominated by turbid conditions during the open-water months. Its habitat consists largely of a main channel, with little to no side-channels, islands or backwaters. The vast majority of the habitat for the Red River would be considered "pool" or "run" habitat. Little submerged aquatic plant growth occurs due to the river's turbid conditions. Fallen trees, log jams and snags provide important physical habitat for Red River fishes.

Aadland et al (2005) performed an extensive review of literature and historical fisheries surveys for the Red River basin. Their observations provide a valuable reference for historical and existing conditions for fisheries resources in the Red River Basin. Aadland et al (2005) reported 57 fish species were identified in the Red River mainstem for surveys conducted from 1962 thru 2000 (Table 30). By comparison, the Sheyenne River had a similar number of fish species collected (56). However, the Wild Rice (23), Maple (30) and Rush (22) rivers had fewer species observed (Table 30).

The Red River is known as perhaps the best trophy channel catfish fishery in the world. Other important sportfish include walleye and sauger. Goldeye are abundant in the Red River and appear to be an important forage base for channel catfish and potentially other species. Common species to the Red River include members of the Cyprinid (minnow) and Catastomid (sucker) families.

Lake sturgeon is a species that was historically found in the Red River Basin, but until recently were extirpated from the watershed. Aadland et al. (2005) recounts the history of the lake sturgeon within the basin. Though the species was found periodically until the 1950s, it was likely extirpated from much of the basin by the early 1900s. Likely factors for extirpation include overharvest, habitat destruction and fragmentation. In 1997, the Minnesota DNR and White Earth Indian Nation began a 20-year program to reintroduce lake sturgeon to the basin. The program called for the annual release of 34,000 fingerling and 600,000 lake sturgeon fry in key sub-basins of the Red River watershed. The current revised lake sturgeon stocking rates are 8,000 fingerling and 200,000 fry. Habitat enhancement and improved habitat connectivity are likely key factors on the long-term success of this reintroduction program.

The river darter also seems to have been extirpated from the Red River mainstem. Several other species have been extirpated from various tributaries but still occur elsewhere in the watershed.

To date, there has been a relatively minimal influx of invasive aquatic species to the Red River Basin. The common carp is the most widely established invasive. Several species have been stocked outside their native range, including white bass and white crappie.

Table 30 includes information on the Fish Species Observed in the Red River Basin between 1962 and 2000. "X" indicates a species presence. "E" indicates species extirpated from the indicated waterbody. No mark represents a species within the Red River Basin, but not found in the indicated waterbody. Source: Aadland et al. 2005.

Table 30 – Fish Species Observed in the Red River Basin. Source: Aadland et al. 2005.

Taxon								
Petromyzontidae	**Scientific Name**	**Common name**	**N or I[1]**	**Red**	**Wild Rice**	**Sheyenne**	**Maple**	**Rush**
	Ichthyomyson castaneus	chestnut lamprey	N	X				
	Ichthyomyson unicuspis	silver lamprey	N	X				
Acipenseridae								
	Acipenser fulvescens[2]	lake sturgeon	N	E				
Lepisosteidae								
	Lepistoseus osseus[2]	longnose gar	N					
Amiidae								
	Amia calva	bowfin	N					
Hiodontidae								
	Hiodon alosoides	goldeneye	N	X		X		
	Hiodon tergisus	mooneye	N	X		X		
Salmonidae								
	Coregonus artedii	ciscoe	N					
	Coregonus clupeaformis	whitefish	N	X				
	Oncorhynchus mykiss	rainbow trout	I			X		
	Salmo trutta	brown trout	I					
	Salvelinus fontinalis	brook trout	I					
	Salvelinus namaycush	lake trout	I					
Catostomidae								
	Carpiodes cyprinus	quillback carpsucker	N	X		X	X	X
	Catostomus commersonii	white sucker	N	X	X	X	X	X
	Hypentelium nigricans	northern hog sucker	N					
	Ictiobus bubalus	smallmouth buffalo	N					
	Ictiobus cyprinellus	bigmouth buffalo	N	X	X	X	X	
	Moxostoma anisurum	silver redhorse	N	X	X	X		
	Moxostoma erythrurum	golden redhorse	N	X		X		
	Moxostoma macrolepidotum	shorthead redhorse	N	X	X	X	X	
	Moxostoma valenciennesi	greater redhorse	N	X		X	X	
Cyprinidae								
	Campostoma anomalum	central stoneroller	N					
	Campostoma oligolepis	largescale stoneroller	N					
	Carassius auratus	goldfish	I	X				
	Cyprinella spiloptera	spotfin shiner	N	X	X	X	X	X
	Cyprinus carpio	common carp	I	X	X	X	X	X
	Hybognathus hankinsoni	brassy minnow	N			X	X	
	Luxilus cornutus	common shiner	N	X		X	X	X

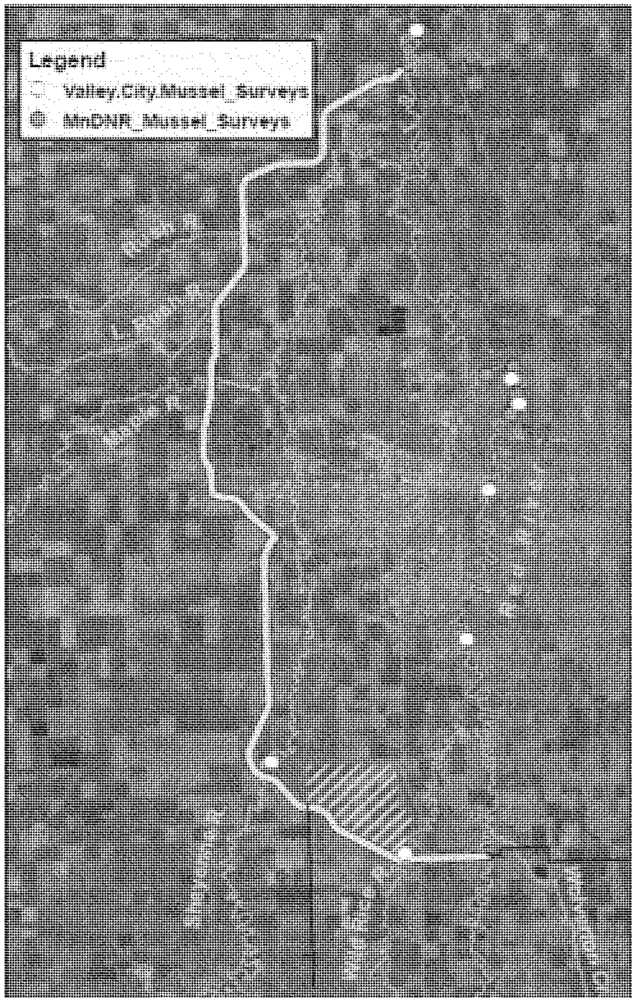
	Macrhybopsis storeriana	silver chub	N	X		X		
	Margariscus margarita	pearl dace	N					
	Nocomis biguttatus	hornyhead chub	N	X		E	E	
	Notemigonus chrysoleucas	golden shiner	N	X		X		
	Notropis anogenus	pugnose shiner	N			E		
	Notropis atherinoides	emerald shiner	N	X		X	X	X
	Notropis blennius	river shiner	N	X	X	X	X	X
	Notropis dorsalis	bigmouth shiner	N	X		X	X	X
	Notropis heterodon	blackchin shiner	N			X		
	Notropis heterolepis	blacknose shiner	N			X		
	Notropis hudsonius	spottail shiner	N	X		X		
	Notropis percobromus	carmine shiner	N			X		
	Notropis rubellus	rosyface shiner	N					
	Notropis stramineus	sand shiner	N	X		X	X	
	Notropis texanus	weed shiner	N					
	Notropis volucellus	mimic shiner	N					
	Phoxinus eos	northern redbelly dace	N			X		X
	Phoxinus neogaeus	finescale dace	N					
	Pimephales notatus	bluntnose minnow	N	X		X	X	X
	Pimephales promelas	fathead minnow	N	X	X	X	X	X
	Platygobio gracilis	flathead chub	I	X				
	Rhinichthys atratulus	blacknose dace	N					
	Rhinichthys cataractae	longnose dace	N	X		X		
	Rhinichthys obtusus	western blacknose dace	N			X	X	
	Semotilus atromaculatus	creek chub	N	X		X	X	X
Ictaluridae								
	Ameiurus melas	black bullhead	N	X	X	X	X	X
	Ameiurus natalis	yellow bullhead	N	X				
	Ameiurus nebulosus	brown bullhead	N	X		X		
	Ictalurus punctatus	channel catfish	N	X	X	X	X	X
	Noturus flavus	stonecat	N	X		X		
	Noturus gyrinus	tadpole madtom	N	X	X	X	X	
Umbridae								
	Umbra limi	central mudminnow	N	X				
Esocidae								
	Esox lucius	northern pike	N	X	X	X	X	X
	Esox masquinongy	muskellunge	I			X		
Osmeridae								
	Osmerus mordax	rainbow smelt	N	X				
Cyprinodontidae								
	Fundulus diaphanus	banded killfish	N	X		E		
Gadidae								
	Lota lota	burbot	N	X				
Percopsidae								
	Percopsis omiscomaycus	trout-perch	N	X	X	X	X	X
Moronidae								
	Morone chrysops	white bass	I	X		X		

Centrarchidae								
	Ambloplites rupestris	rock bass	N	X	X	X		
	Lepomis cyanellus	green sunfish	N	X		X	X	
	Lepomis gibbosus	pumpkinseed	N		X	X		
	Lepomis humilis	orangespotted sunfish	N	X		X		
	Lepomis macrochirus	bluegill	N	X		X		
	Micropterus dolomieu	smallmouth bass	N	X		X		
	Micropterus salmoides	largemouth bass	N			X		
	Pomoxis annularis	white crappie	N	X		X	X	
	Pomoxis nigromaculatus	black crappie	N	X	X	X	X	
Percidae								
	Etheostoma caeruleum	rainbow darter	N					
	Etheostoma exile	Iowa darter	N		X	X	X	X
	Etheostoma microperca	least darter	N					
	Etheostoma nigrum	johnny darter	N	X	X	X	X	
	Perca flavescens	yellow perch	N	X	X	X		
	Percina caprodes	logperch	N	X				
	Percina maculata	blackside darter	N	X	X	X	X	X
	Percina shumardi	river darter	N	E		E		
	Sander canadensis	sauger	N	X		X	X	X
	Sander vitreus	walleye	N	X	X	X		X
Scianidae								
	Aplodinotus grunniens	freshwater drum	N	X	X	X		X
Cottidae								
	Cottus bairdi	mottled sculpin	N					
	Cottus cognatus	slimy sculpin	N					
	Cottus ricei	spoonhead sculpin	N					
Gasterosteidae								
	Culaea inconstans	brook stickleback	N		X	X	X	X
	Pungitius pungitius	ninespine stickleback	N					
[1] Species that are native (N) or introduced (I) to the Red River Basin.								
[2] Species which are known only from historical records and most likely no longer exist in the Red River basin.								

4.2.1.8.2 Mussel Communities

The Red River and its tributaries also contain communities of freshwater mussels. Surveys performed recently in the study area provide insight into mussel resources (Figure 46). Mussel sampling from the Red River in the study area was dominated by threeridge, pocketbook and pink heelsplitter (MnDNR Data; Valley City State University Data). Relative abundance and diversity could be considered low to moderate. Surveys by MnDNR had a Catch-Per-Unit-Effort of 40 to 94 mussels per hour of qualitative dive surveys, with three to six species collected per site. Special status species observed included Wabash pigtoe (ND), black sandshell (ND and MN) and mapleleaf (ND).

Figure 46 – Location of Recent Mussel Surveys



Mussel sampling also was recently performed on the Wild Rice and Sheyenne rivers (Figure 46; Valley City State University Data). Observations on the Wild Rice found only 11 mussels in 120 minutes of qualitative wading surveys. This included five species, with black sandshell most abundant. Observations on the Sheyenne River near the proposed diversion alignment found 56 mussels (nine different species) with the same search effort. The two most dominant species included three ridge and black sandshell. Wabash pigtoe and mapleleaf also were collected from the Sheyenne River site.

Zebra mussels, an invasive mollusk, are becoming established within the basin and may become more abundant over time within the study area. While the project would not be anticipated to contribute to the spread of zebra mussels, it is possible that additional project maintenance could be required if zebra mussel densities become high.

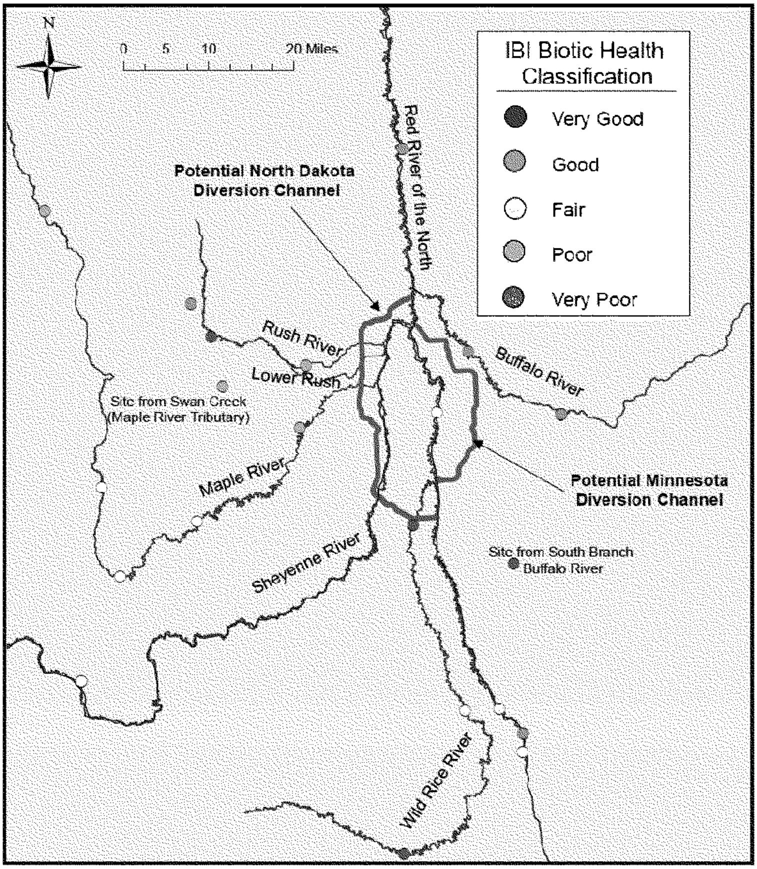
4.2.1.8.3 Habitat Quality and Biotic Integrity

Previous studies have characterized the biotic health of the Red River and select tributaries, including Index of Biotic Integrity (IBI) studies of fish and macroinvertebrates. USEPA (1998) evaluated fish communities in the Red River, and characterized river health as ranging between "poor" to "good" based on fish community composition. The survey reach observed at Fargo would be characterized as "fair" based on their IBI criteria (USEPA 1998, Figure 47).

USEPA (1998) observations classified biotic integrity as "very poor" or "poor" for sites on the Wild Rice, Maple and Rush rivers that were within or closest to the study area (Figure 47). The nearest survey reach on the Sheyenne was classified as "fair" but was considerably upstream of the study area. Biotic health for the Sheyenne in the study area is probably more degraded, similar to the other tributaries with information closer to the study area. Tributary habitat upstream of the study area appears to improve for some tributaries, with habitat classified as "fair" or "good" in some sections of the Rush, Maple and Sheyenne rivers.

Physical tributary habitat in the study area has been heavily modified, which is reflected in the IBI scores. The Rush and Lower Rush rivers have been channelized and straightened through the study area to their confluence with the Sheyenne River. The Sheyenne River has been heavily modified from several actions. The Horace/West Fargo Diversion includes multiple control structures and diversion channels that are operated with flows as low as a 50-percent chance event. During some flood events, flows are actually blocked at West Fargo, with the entire river routed through a flood diversion channel. Additional features along the lower Sheyenne River include a low-head dam and several bridge crossings that may constrict flow. Ultimately, these features cumulatively result in modified hydraulic and geomorphic conditions in the Sheyenne, which adversely affect its aquatic habitat.

Figure 47 - Index of Biotic Integrity classification for select sites on the Red River and adjacent tributaries (from EPA 1998).



Additional actions such as tiling, ditching and draining have been widely done across the study area, resulting in altered hydraulic and geomorphic conditions in tributaries. Several tributary reaches in the study area also have limited or no riparian habitat along their corridor. These altered conditions directly affect aquatic habitat quality, and may be most apparent with tributaries on the Red River valley floor, within or adjacent to the study area.

Although tributary habitat may be degraded around the study area, tributaries are important for many species within the Red River basin. Areas of greatest value are typically upstream of the valley floor in areas with more diverse habitat. Much of the Red River mainstem lacks rock/cobble habitat that would be utilized by fishes that spawn in riffle habitat. However, such habitat is found in adjacent tributaries, particularly within high-gradient areas upstream of the study area where streams descend through old beach ridges of glacial Lake Agassiz and glacial moraines (Aadland et al 2005).

4.2.1.8.4 Aquatic Habitat Connectivity

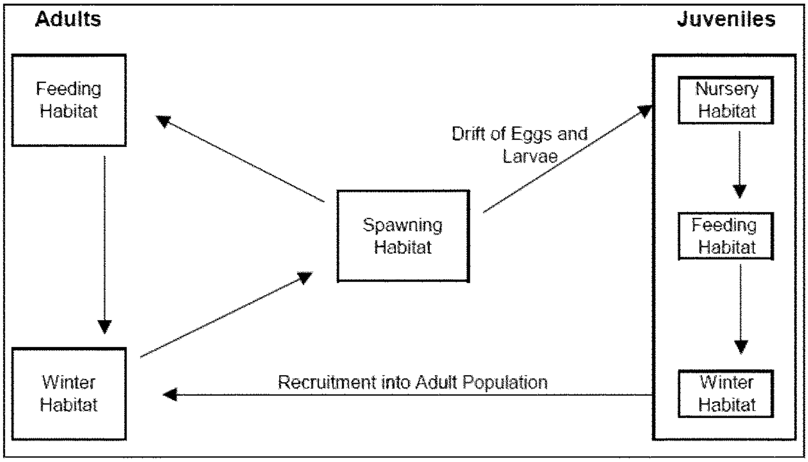
Connectivity is an important attribute of aquatic habitat for river fishes. Connectivity refers to the continuous nature of aquatic habitats in main channels, floodplain water bodies and tributaries. Natural rivers contain a heterogeneous mosaic of aquatic habitats that are very dynamic in both a spatial and temporal sense. River habitats can substantially vary over scales from short- (e.g., flood events) to medium- (e.g., seasonal) or long-term (annual, decadal, or longer). Fish in rivers have evolved migratory and life history strategies that take advantage of these complex, changing riverscapes.

Habitat connectivity is important in terms of fulfilling seasonal and life-stage specific habitat needs for river fishes. Fish undergo alimental (food procurement), climatic (seasonal habitat movements), and gametic (reproduction) migrations in rivers (McKeown 1984) (Figure 48). In addition to the conceptual model by McKeown, others (e.g., Fauch et al. 2002; Schlosser 1991) have identified refinements regarding migrations that are common features of fish life histories including migrations that occur between different feeding habitats, and migrations associated with refugia during catastrophic events such as floods, droughts, and extreme water quality conditions (i.e., high temperature, low dissolved oxygen).

Dams and similar structures reduce the connectivity of aquatic habitat by restricting movement of river fish. Impeded fish movements resulting from dams have been implicated in altering fish community structure and declining fish populations in rivers throughout the world (Northcote 1998; Pringle et al. 2000). Restrictions on movements of migratory fish in a river system can potentially limit the extent and quality of habitats that they can occupy. Effects of reduced access to habitats can be expressed at the individual, population, and community levels.

Information on the effects of dams and reduced connectivity of most inland fish populations is generally scarce. However, impeding migrations that freshwater fish use to optimize growth, reproduction and survival can ultimately affect fish production (Northcote 1978). Reduced access to prime foraging habitat can result in greater expenditure of energy for foraging and reduce growth of individual fish. Reduced access to suitable winter habitat can limit winter survival. Restrictions on movements of migratory fish can have significant adverse effects on pre-spawning movements, can limit access to suitable spawning habitats, and limit the size of spawning aggregations.

Figure 48 - Pattern of seasonal movements of many Red River of the North fishes (after McKeown 1984)



A wide range of fish species potentially migrate long distance to fulfill life-history requirements in the Red River basin. In many cases, it may be difficult to define whether or not a species is specifically "migratory." Species in the basin that likely perform regular migrations include, but are not limited to, lake sturgeon, channel catfish, walleye, sauger, goldeye, mooneye, northern pike and several Catastomid (sucker) species. In addition to the tributaries listed above in the study area, tributaries throughout the basin may have fish populations that migrate back and forth from the Red River.

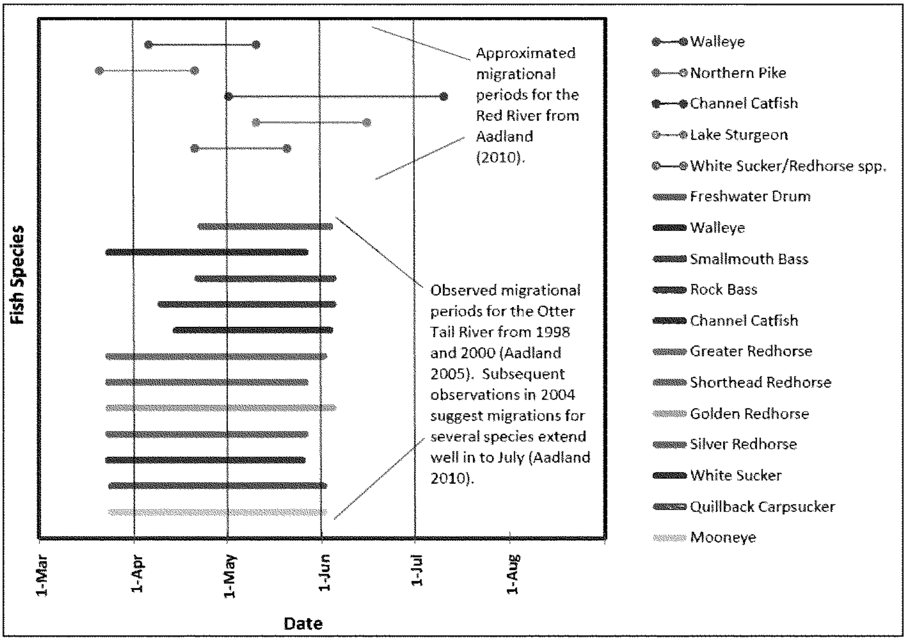
Aadland et al. (2005) provided a summary of fish migration observations through a fish bypass channel on the Otter Tail River, a Minnesota tributary upstream of the study area (Table 31, Figure 49). The sampling location was about eight miles upstream of the confluence of the Otter Tail and the Bois de Sioux River; the confluence of these rivers forms the Red River. Sampling was done during the spring of 1998 and 2000 over a period of a couple months. Though the study included typical limitations due to sampling gears and methodology, the observations provide insight into seasonal upstream fish migrations from the Red River into the Otter Tail River.

Table 31 – Upstream migrating fishes caught on Otter Tail River (Aadland et al 2005).

Species	Common Name	Total Catch	% of Total	Peak Catch	Earliest Catch	Latest Catch
Hiodon alosoides	goldeneye	2	<1	May 19	May 19	Jun 1
Hiodon tergisus	mooneye	204	5	May 18	Mar 24	Jun 1
Esox lucius	northern pike	6	<1	Apr 26	Mar 24	May 3
Cyprinus carpio	common carp	5	<1	May 11	Apr 14	May 26
Carpiodes cyprinus	quillback carpsucker	181	4	May 14	Mar 24	Jun 1
Ictiobus cyprinellus	bigmouth buffalo	2	<1	May 26	Mar 30	May 26

Catostomus commersonii	white sucker	75	2	Mar 30	Mar 23	May 25
Moxostoma anisurum	silver redhorse	369	9	May 3	Mar 23	May 26
Moxostoma erythrurum	golden redhorse	435	11	May 3	Mar 23	Jun 4
Moxostoma macrolepidotum	shorthead redhorse	1707	43	May 3	Mar 23	May 26
Moxostoma valenciennesi	greater redhorse	133	3	May 3	Mar 23	Jun 1
Ameiurus melas	black bullhead	4	<1	May 11	Apr 23	May 12
Ameiurus nebulosus	brown bullhead	1	<1	May 3	May 3	May 3
Ictalurus punctatus	channel catfish	679	17	Apr 29	Apr 14	Jun 3
Noturus flavus	stonecat	4	<1	Apr 15	Apr 14	Apr 15
Ambloplites rupestris	rock bass	27	1	May 11	Apr 9	Jun 4
Micropterus dolomieu	smallmouth bass	34	1	Apr 23	Apr 21	Jun 4
Pomoxis nigromaculatus	black crappie	4	<1	May 25	Apr 26	May 12
Sander canadensis	sauger	1	<1	Apr 21	Apr 21	Apr 21
Sander vitreus	walleye	65	2	Apr 22	Mar 23	May 26
Aplodinotus grunniens	freshwater drum	65	2	May 26	Apr 22	Jun 3

Figure 49 - Migrational periods for several fish of the Otter Tail and Red Rivers, MN.



Aadland et al (2005, Table 31) noted 21 species of fish captured at the upstream end of the fishway. The timing and duration of migration varied by species, but often occurred over a period of several weeks between late March and early June. The date of peak catch was also variable, but was often in late April or the first couple weeks of May.

lists the upstream migrating fishes caught in a trap net at the upstream end of the Breckenridge fishway on the Otter Tail River in 1998 and 2000. Catches represent 14 net-days from April 7 to June 4, 1998 and 22 net-days from March 23 to June 1, 2000 (Aadland et al. 2005). Additional observations from this location in 2004 suggested fish migrations of several species could extend well into July (Aadland 2010).

Aadland (2010) provided approximate migration periods for select Red River fishes (Figure 49). This includes an approximated migrational period for lake sturgeon which was not captured during observations on the Otter Tail River. For the fish identified, migrational periods on the Red River would be expected to occur over a period of a month or more. Key Red River species of concern include lake sturgeon and channel catfish. Lake sturgeon would be expected to migrate from early- to mid-May thru mid-June. Channel catfish would be expected to migrate over a period of a couple months, generally from May through early July. Aadland (2010) noted channel catfish migrations on the Otter Tail in 2004 began in late-April. However, he observed that the largest individuals (600 mm and larger) were captured in July. Aadland (2010) noted these large fish were likely spawners and the late migration of large individuals could have significant ramifications for catfish populations. Thus, migration during these summer months could be particularly important for these species.

Connectivity in the Red River basin has been interrupted through the construction of numerous dams. This includes eight low-head dams constructed on the Red River mainstem within the United States (Table 32), as well as the Lockport dam in Manitoba, Canada. Aadland et al (2005) reported over 500 dams exist on Red River tributaries within the U.S. This has limited the ability for fish populations to move throughout the Red River basin, including movement between the Red River and upstream tributary habitats.

Table 32 – Distribution of low-head dams on the Red River of the North.

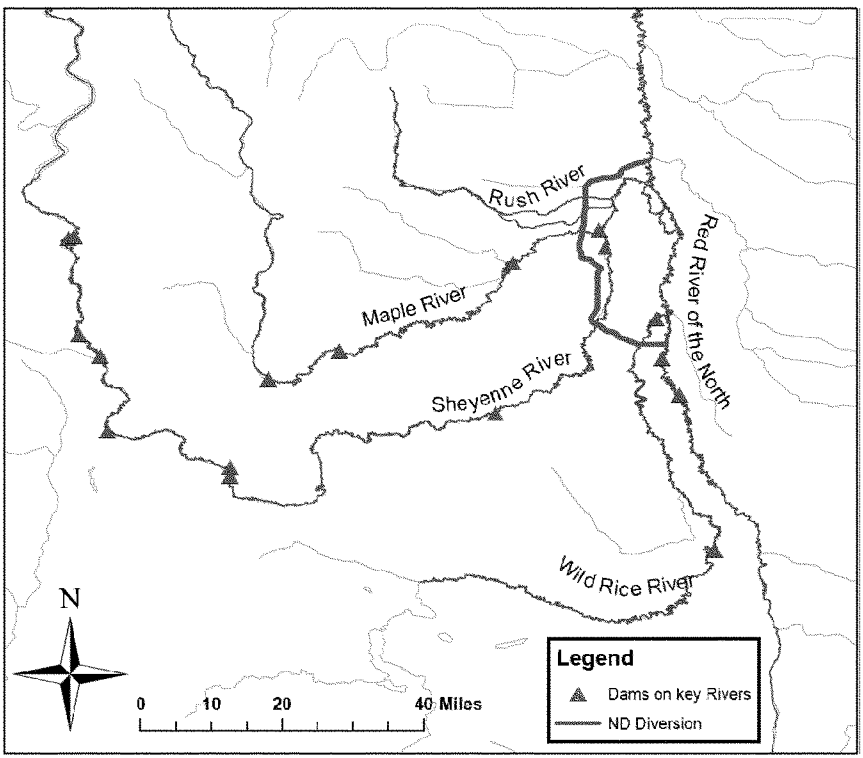
The Red River crosses the international border into Canada at River Mile 158.0.

River Mile	Location	Fish Passage Status
207.1	Drayton, North Dakota	Planning Study Underway
296.1	Grand Forks, North Dakota-East Grand Forks, Minnesota	Rock-Rapids Fishway Completed 2001
448.9	North Dam, Fargo-Moorhead (12th/15th Avenue)	Rock-Rapids Fishway Completed 2002
452.2	Midtown Dam, Fargo-Moorhead (4th Street)	Rock-Rapids Fishway Completed 1999
458.1	South Dam, Fargo-Moorhead (32nd Avenue)	Rock-Rapids Fishway Completed 2003
482.7	Hickson, North Dakota	Construction Scheduled for 2011
496.6	Christine Dam, North Dakota	Construction Scheduled for 2011
546.4	Wahpeton, North Dakota-Breckenridge, Minnesota	Rock-Rapids Fishway Completed 2000

Connectivity between the Red River and adjacent tributaries in the study area is also poor as a result of several existing dams (see Figure 50). The Maple, Sheyenne and Wild Rice rivers all have low-head dams between their confluence with the Red River and the proposed diversion alignment for the North Dakota alternatives (Figure 50). Figure 50 does not include dams that have been retrofitted for fish passage and additional dams are also found upstream on these tributaries, further limiting connectivity.

The Sheyenne River especially has limited connectivity between the Red River and habitat upstream of the study area. A low-head dam in West Fargo on the lower Sheyenne limits or eliminates connectivity during low-flow conditions. Conversely, connectivity during high flow conditions is also limited or non-existent due to the flood project at Horace and West Fargo. This includes multiple control structures that divert all river flow into a flood diversion channel when flows approach a 50-percent chance event. Any biotic connectivity would require fish to migrate upstream through this flood channel, then through a small denil-style fishway at the Horace control weir. The effectiveness of this fishway has not been evaluated. Ultimately, there is likely poor biotic connectivity between the lower Sheyenne and Red rivers under existing conditions.

Figure 50 – Existing dams on the Red River and Tributaries

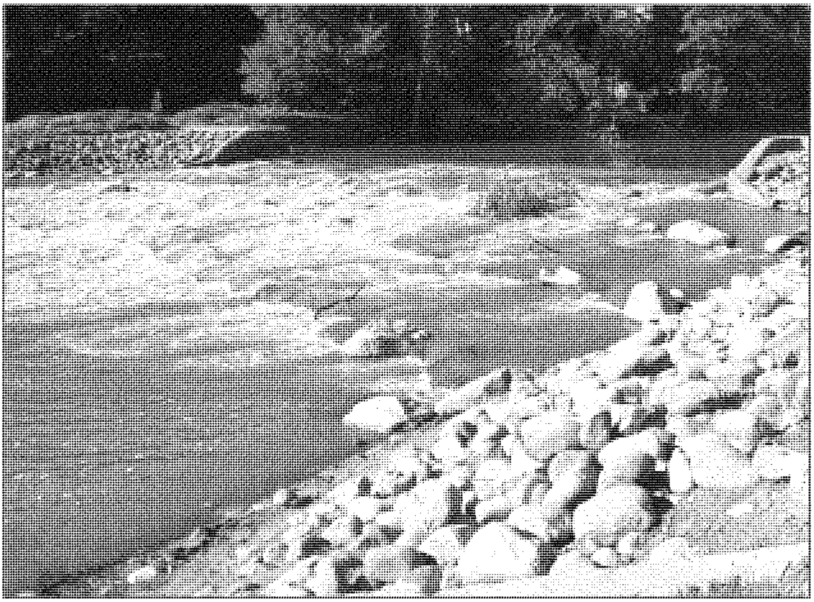


The Rush River includes at least one rock and culvert structure that limits biotic connectivity. Fish migrations are possible when this structure is overtopped. However, under most conditions, fish would have to migrate through one of two culverts to pass this structure.

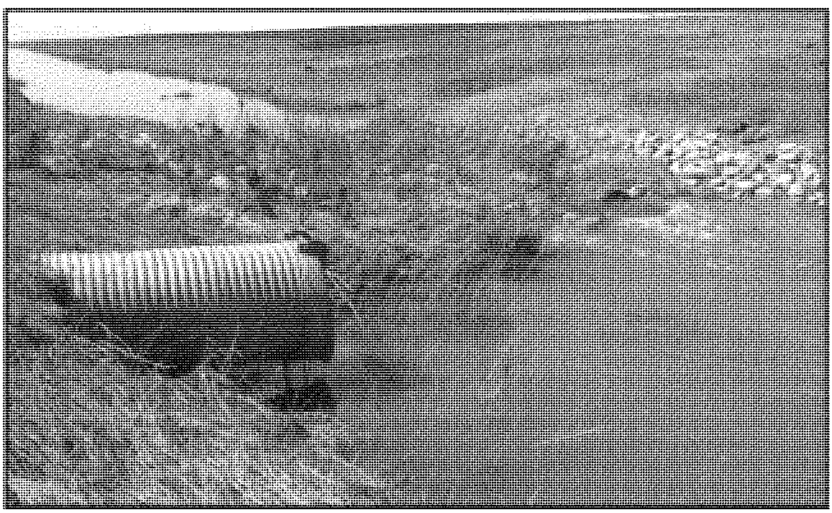
Picture 7 - Wild Rice Dam on the Wild Rice River, just downstream of the diversion channel alignment for the North Dakota alignment alternatives. Photo from June 23, 2010

Extensive work has been done to improve connectivity and fish passage on the Red River mainstem. Of the eight dams on the Red River mainstem, five have implemented rock-riffle structures to facilitate fish passage (Table 32). Resource agency biologists believe these projects provide the opportunity for free migration to all species of fish approaching 100-percent of the time. The remaining three dams currently have planning studies underway that are also looking to implement similar fish passage opportunities. If implemented, these projects would facilitate the reconnection of over 300 miles of Red River mainstem habitat. However, the likelihood of implementation of these three projects is unknown. Construction projects at Christine and Hickson dams are scheduled for 2011. The project at Drayton Dam appears much less certain given likely construction costs and uncertain funding sources.

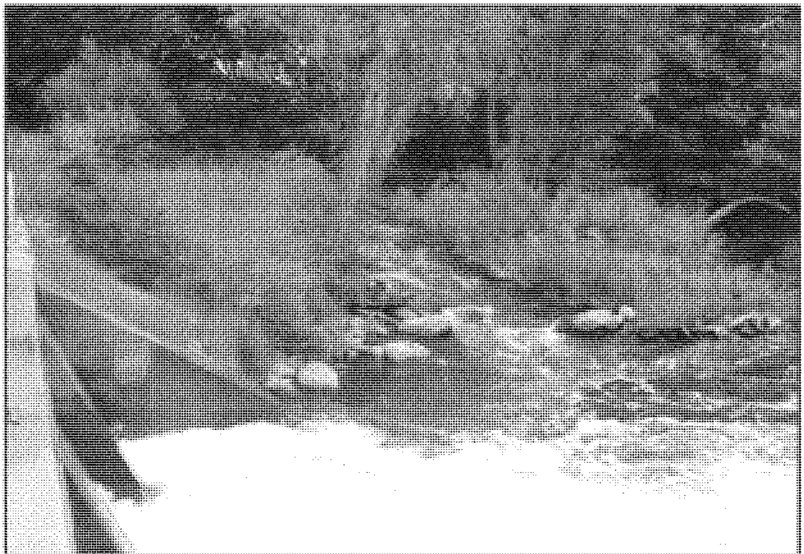
Outside of the study area, Red River tributaries have received attention for improving fish passage opportunities. These include 30 projects to provide for improved fish movement; a majority of these have been done on Minnesota tributaries.



Picture 8 - Example of a rock-rapids fish passage structure at North Dam, Red River of the North, Fargo, ND. Project completed in 2002.



Picture 9 - Rock and culvert structure on the Rush River within the study area. Photo from April 22, 2010.

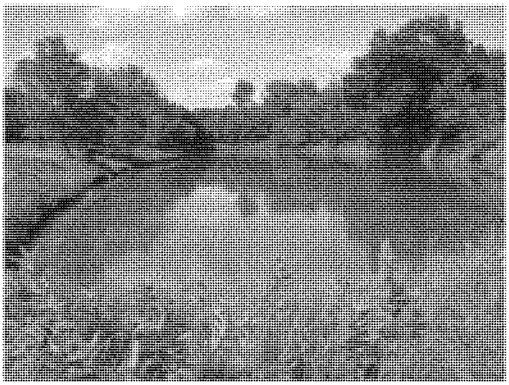


Picture 10 - Example of a fish bypass channel at a dam on the Otter Tail River near Fergus Falls, MN. Project completed in 2002. Photo and information source: Aadland 2010.

4.2.1.9 Riparian Habitat

A riparian zone is the area between a body of water and the adjacent upland, identified by soil characteristics and distinctive vegetation that requires an excess of water. It includes wetlands and those portions of the floodplain that support riparian vegetation. Generally it is comprised of trees and shrubs as well as understory vegetation, including a variety of grasses and forbs. Eastern North Dakota riparian zones are dominated by green ash and elm trees whereas cottonwoods are prevalent in western zones of the state. The riparian zones along the Wild Rice, Maple, Rush and Lower Rush Rivers consist of mostly open farm land. The riparian zones along the Sheyenne and Red River consist of small strips of bottomland hardwoods including, but not limited to, cottonwood, green ash, bur oak, basswood, American elm, silver maple, and hackberry. Although this habitat type makes up a small area it is an important home to numerous wildlife species and is vital to stream health.

The narrow riparian zone is in a relatively natural condition. The remaining wooded riparian areas are an important wildlife and aesthetic resource. The riparian woodlands are essentially the only wooded habitat remaining in this predominantly agricultural area. Tree species identified in these areas include bur oak, American linden, eastern cottonwood, American elm, boxelder, green ash, silver maple, buckthorn, and hackberry. Woodland was never very common in the prairie environment, but it is extremely important as nesting, breeding, and overwintering habitat for a number of birds, mammals, and reptiles



Picture 11 – Riparian area along Wild Rice River.

4.2.1.10 Wetland Habitat
Based on the National Wetland Inventory (NWI) database there are 4,626 acres of wetlands in the study area (Figure 51, Table 33). Wetlands outside of the area in Figure 51 were not calculated; the majority of these lands are adjacent to the rivers and streams in the area. This number represents less than 0.05-percent of the area within the study area. Table 33 lists the existing wetlands in the study area by type and size. Definitions of wetland types and a detailed photo log of wetlands can be found in Appendix F.

It is important to point out that a detailed wetland delineation of wetlands has been conducted on potentially impacted areas and there were many acres of farmed wetlands identified. These wetland types are not reported by the NWI database, meaning that the 4,626 acres understates what actually exists in the area today. Based on the delineation and the changes from a drier to wetter climate in recent years there are more wetlands within the study area than initially reported in the DEIS.

There are numerous wetland restoration programs within the Red River Basin, but implementation has often been hindered by cost and/or land availability. The objectives of the wetland restoration programs include providing flood storage, improving water quality, and increasing wildlife and recreation opportunities.

Due to increasing pressure to either urbanize or improve drainage on cropland, it is anticipated that wetland acreage will either remain the same or decrease within the study area under the without project condition.

Picture 12 – Floodplain Forest.

Picture 13 – Arrowhead plants near an oxbow.

Figure 51 – Existing Wetlands

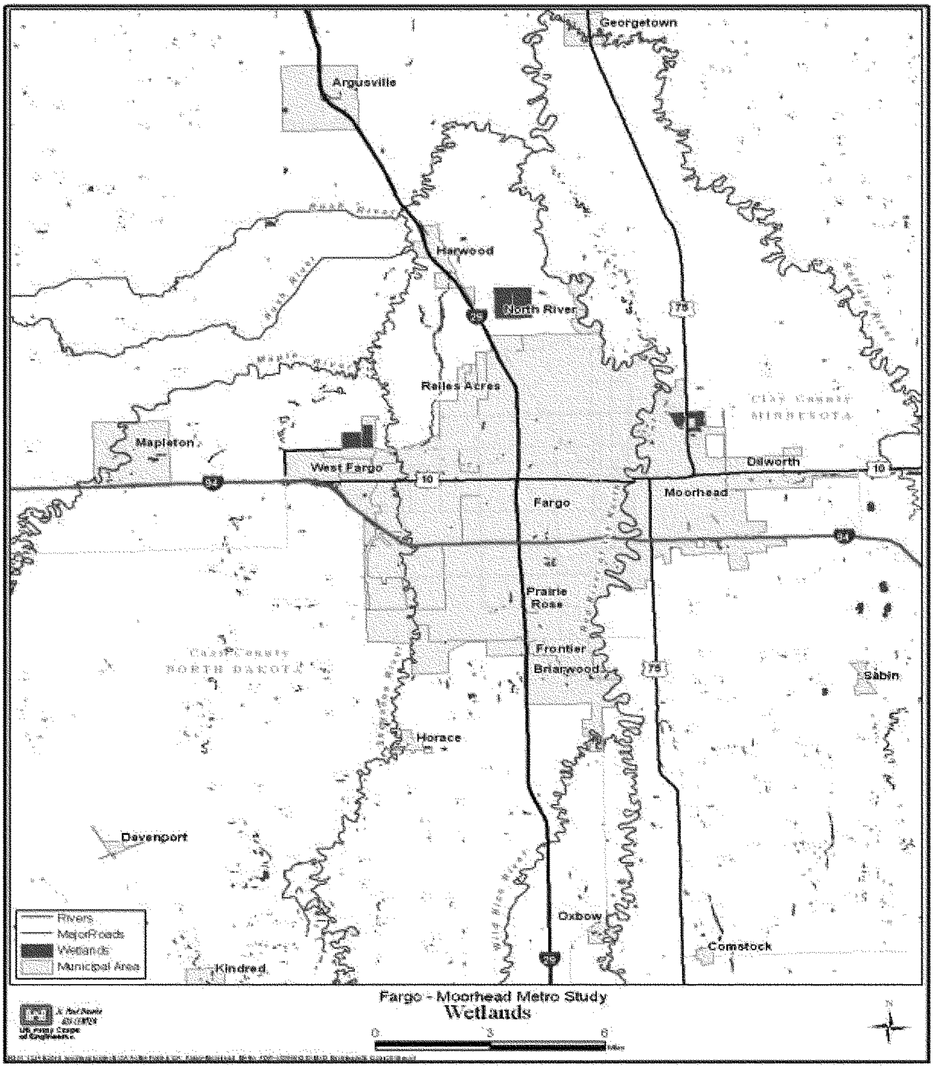


Table 33 – List of existing wetlands by type and number of acres from the NWI database.

Type	Wetland Code	Acres
Lacustrine, Littoral, Aquatic Bed, Intermittently Exposed, Excavated	L2ABGx	761.44
Lacustrine, Littoral, Unconsolidated bottom, Artificially Flooded, Intermittently Exposed, Excavated	L2UBKGx	91.01
Palustrine, Aquatic Bed, Semipermanently Flooded	PABF	77.25
Palustrine, Aquatic Bed, Semipermanently Flooded, Diked/Impounded	PABFh	1.04
Palustrine, Aquatic Bed, Semipermanently Flooded, Excavated	PABFx	26.61
Palustrine, Emergent, Aquatic Bed, Semipermanently Flooded	PEM/ABF	24.28
Palustrine, Emergent, Forested, Broad-Leaved Deciduous, Seasonally Flooded	PEM/FO1C	7.07
Palustrine, Emergent, Forested, Seasonally Flooded	PEM/FOC	28.64
Palustrine, Emergent/Scrub-Shrub, Broad-Leaved Deciduous, Seasonally Flooded	PEM/SS1C	26.34
Palustrine, Emergent/ Unconsolidated Bottom, Semipermanently Flooded	PEM/UBF	2.09
Palustrine, Emergent, Temporarily Flooded	PEMA	163.05
Palustrine, Emergent, Temporarily Flooded, Partially Drained/Ditched	PEMAd	181.92
Palustrine, Emergent, Temporarily Flooded. Excavated	PEMAx	24.83
Palustrine, Emergent, Seasonally Flooded	PEMC	174.59
Palustrine, Emergent, Seasonally Flooded, Partially Drained/Ditched	PEMCd	71.22
Palustrine, Emergent, Seasonally Flooded, Excavated	PEMCx	242.63
Palustrine, Emergent, Semipermanently Flooded	PEMF	69.33
Palustrine, Emergent, Semipermanently Flooded, Partially Drained/Ditched	PEMFd	7.13
Palustrine, Emergent, Semipermanently Flooded, Excavated	PEMFx	32.12
Palustrine, Forested/ Emergent, Seasonally Flooded	PFO/EMC	3.98
Palustrine, Forested, Broad-Leaved Deciduous/ Emergent, Seasonally Flooded	PFO1/EMC	0.55
Palustrine, Forested, Broad-Leaved Deciduous, Temporarily Flooded	PFO1A	7.58
Palustrine, Forested, Broad-Leaved Deciduous, Seasonally Flooded	PFO1C	5.21
Palustrine, Forested, Temporarily Flooded	PFOA	31.53
Palustrine, Forested, Temporarily Flooded, Drained/Ditched	PFOAd	3.20
Palustrine, Forested, Seasonally Flooded	PFOC	10.56
Palustrine, Scrub-Shrub, Emergent, Seasonally Flooded	PSS/EMC	7.17
Palustrine, Scrub-Shrub, Emergent, Seasonally Flooded, Excavated	PSS/EMCx	10.33
Palustrine, Scrub-Shrub, Forested, Seasonally Flooded	PSS/FOC	5.38
Palustrine, Scrub-Shrub, Broad-Leaved Deciduous, Emergent, Seasonally Flooded	PSS1/EMC	1.33
Palustrine, Scrub-Shrub, Broad-Leaved Deciduous, Seasonally Flooded	PSS1C	11.41
Palustrine, Scrub-Shrub, Broad-Leaved Deciduous, Seasonally Flooded, Partially Drained/Ditched	PSS1Cd	0.91
Palustrine, Scrub-Shrub, Temporarily Flooded	PSSA	13.25
Palustrine, Scrub-Shrub, Seasonally Flooded	PSSC	2.57
Palustrine, Unconsolidated Bottom, Semipermanently Flooded	PUBF	6.47
Palustrine, Unconsolidated Bottom, Semipermanently Flooded, Diked/Impounded	PUBFh	2.97
Palustrine, Unconsolidated Bottom, Semipermanently Flooded, Excavated	PUBFx	21.79
Palustrine, Unconsolidated Bottom, Intermittently Exposed	PUBG	0.31
Palustrine, Unconsolidated Bottom, Intermittently Exposed, Excavated	PUBGx	15.54

Palustrine, Unconsolidated Bottom, Artificially Flooded, Intermittently Exposed, Excavated	PUBKGx	74.71
Riverine, Lower Perennial, Unconsolidated Bottom, Intermittently Exposed	R2UBG	241.53
Riverine, Lower Perennial, Unconsolidated Bottom, Permanently Flooded	R2UBH	2114.90
Riverine, Lower Perennial, Unconsolidated Shore, Temporarily Flooded	R2USA	2.08
Riverine, Lower Perennial, Unconsolidated Shore, Seasonally Flooded	R2USC	2.10
Riverine, Intermittent, Streambed, Semipermanently Flooded	R4SBF	0.69
Riverine, Intermittent, Streambed, Semipermanently Flooded, Excavated	R4SBFx	15.33
Total Wetland Acres		4625.97

4.2.1.11 Upland Habitat

Upland habitat in the study area is mainly cropland, with a mixture of hayed pasture, hobby farms and suburban dwellings. Wooded areas include mostly a mixture of bottomland hardwood tree species and low vegetation. The small percentage of upland wooded areas are made up of shelter belts planted near farmsteads and homes or along field edges, these shelter belts include some coniferous trees but mostly small shrubs and fast growing tree species. Wildlife species present within the project vicinity include typical urban and farmland species such as rabbits, squirrels, raccoons, white-tailed deer, and various songbirds.

Picture 14 – Wheat field.

4.2.1.12 Terrestrial Wildlife

Birds and mammals that inhabit the rural portions of the study area include raptors, gray partridge, pheasant, mourning dove, waterfowl, fox squirrel, white-tailed deer, red fox, raccoon, mink, badger, striped skunk, white-tailed jackrabbit, beaver, muskrat, and numerous song birds. The riparian vegetation (forested floodplain) associated with the Red, Wild Rice and Sheyenne rivers represents most of the terrestrial wildlife habitat that presently exists within the study area. Other than this limited riparian habitat, wildlife resources in the study area are limited to those species that can reside in drainage ways, shelterbelts, cultivated fields and road right-of-ways (ROWs).

Habitat within the urban areas is limited to manicured lawns and landscaped areas. These areas provide only limited habitat for wildlife species. Therefore, wildlife resources are primarily limited to songbirds, reptiles, amphibians and small mammals.

4.2.1.13 Endangered Species

4.2.1.13.1 North Dakota Federal

According to United States Fish and Wildlife Service's (USFWS), there are two Federally listed threatened or endangered species listed for Cass and Richland Counties, North Dakota: the whooping crane (*Grus americanus*) and the gray wolf (*Canis lupus)*, both of which are endangered.

4.2.1.13.1.1 Whooping Crane

The whooping crane was listed as endangered by the USFWS on June 2, 1970. The whooping crane is the tallest bird in North America. It is a white bird with black wingtips and red markings on the head. Young birds have a brown-mottled appearance until their second summer. Whooping cranes are 5 feet tall and have wingspans of 7 feet. They fly with a slow downward flap and a rapid upstroke, and often migrate with the smaller, gray, sandhill crane. Their trumpet-like call carries for miles (United States Geological Survey [USGS] 2009b).

Whooping cranes inhabit shallow wetlands that are characterized by cattails, bulrushes and sedges. They can also be found in upland areas, especially during migration. Whooping cranes feed on crabs, crayfish, frogs, and other small aquatic life as well as plants (USGS 2009b).

The historical breeding range of the whooping crane extended from Illinois, northwest through North Dakota, and up to the Northwest Territories. The last nesting record for North Dakota was in McHenry County in 1915. The birds historically wintered along the Gulf of Mexico (USGS 2009b). In the 1940s, there were an estimated 21 whooping cranes left in the world. Most were from a flock that wintered at the Aransas National Wildlife Refuge on the coast of Texas. These birds are known to breed in the Wood Buffalo National Park. Today, there are approximately 145 whooping cranes in the wild. About 132 birds are in the Aransas-Wood Buffalo flock. The Aransas-Wood Buffalo population migrates through North Dakota. The fall migration occurs from late September to mid-October and the spring migration occurs from late April to mid-June. Although the bird can show up in all parts of North Dakota, most sightings occur in the western 2/3 of the state (USGS 2009b). No sightings have been recorded in the study area.

Loss of habitat and poaching are the main reasons for the whooping cranes decline (USGS 2009b).

4.2.1.13.1.2 Gray Wolf
The gray wolf was listed as endangered by USFWS on March 11, 1967. It is the largest of the canines, weighing up to 80 lbs, and can reach a length of 6.5 feet. The gray wolf is also known as the "timber wolf," "arctic wolf" in the arctic, and "tundra wolf" in the tundra. It has a gray fur coat with long tawny colored legs, a narrow chest, and tawny-colored flanks; it can live up to 13 years.

The gray wolf can reach speeds up to 45 mph and has excellent sense of smell and hearing. They are excellent hunters, often hunting in packs where they seek large prey, such as moose, elk, or deer. When they hunt alone they focus on smaller prey such as beavers, rabbits, or hares. The gray wolf can travel up to 30 miles a day searching for prey.

There are an estimated 7,000 to 9,000 wolves in Alaska and more than 3,500 in the lower 48 states, although none are reported in the study area. The main threats to the survival of the gray wolf were hunting and trapping because it was thought of as a nuisance, and habitat loss due to human encroachment into wolf territories. The gray wolf population was nearly wiped out, but now the gray wolf is legally protected and is said to be thriving and may even be taken off the endangered species list.

4.2.1.13.2 North Dakota State
The North Dakota Natural Heritage Program within the North Dakota Parks and Recreation Department was contacted to obtain information on North Dakota's species of concern within Cass County (Dirk 2006a; 2006b). Based on the supplied information, it was determined that 52 plant and animal species of concern in North Dakota have the potential to occur in Cass County. These 52 species and the type of habitat utilized/required by each species are provided in Section 1.9.3 of Appendix F. Supplied maps were used to identify documented occurrence of each species in Cass County, which in turn was used to determine the potential for each of the species to be present in the study area. Seven of the 52 species that have the potential to occur in Cass County have documented occurrences in the study area. These seven species included one fish species (Northern redbelly dace), three mussels (Wabash pigtoe, Black Sandshell, and Mapleleaf) one plant (blue cohosh) and two bird species (whip-poor-will and northern cardinal).

4.2.1.13.3 Minnesota Federal
Clay County, Minnesota has one species listed on the Federal threatened species list, the Western prairie fringed orchid (*Platanthera praeclara*), and one species on the candidate species list, the Dakota skipper (*Hesperia dacotae*). There are no listed species in Wilkin County, Minnesota.

4.2.1.13.3.1 Western Prairie Fringed Orchid
The western prairie fringed orchid was listed as threatened by the USFWS on September 28, 1989. The orchid is perennial and distinguished by large, white flowers that come from a single stem. Up to 20 flowers may occur on a single plant and two to five narrow leaves hug the stem. The flower is

fringed on the margins, giving it a feathery appearance. The orchid can grow up to three feet high (USGS 2009a).

The vegetative shoots of the western prairie fringed orchid emerge in late May. Flowers do not emerge until mid-June to late July. The entire plant can display flowers for about 21 days with individual flowers lasting up to 10 days. Flowers must be pollinated for seed production. Pollination appears to be accomplished only by hawkmoths with the microscopic seed being dispersed by the wind in early fall (USGS 2009a).

The western prairie fringed orchid occurs most often in remnant native prairies and meadows, but has also been observed at disturbed sites. In the southern parts of its range it is more likely to be found in mesic upland prairies and in the north more frequently in wet prairies and sedge meadow. It is also found in prairies swales and sand dune complexes that are fed by shallow groundwater (Sather 1991). Also, the orchid is well adapted to survive fires (USGS 2009a).

The western prairie fringed orchid was historically found throughout the tall grass regions of North America. This included the Dakotas, Nebraska, Kansas, Oklahoma, Missouri, Iowa, Minnesota and Manitoba. The Mississippi River was the eastern limit of its range (USGS2009a). The Red River Valley of Manitoba, Minnesota and North Dakota represented the heart of the orchid's range (Sather 1991). Presently, there are at least 37 separate populations remaining in seven states. In North Dakota, there is a large scattered population in the Sheyenne National Grasslands in the southeastern part of the state (USGS 2009a). In Minnesota, there are two populations known: one in Pipestone National Monument and one in Pembina Trail Preserve Scientific and Natural Area (Minnesota Seasons 2009). It is unlikely any western prairie fringed orchids are in the study area.

The main reason for the decline of the western prairie fringe orchid is the conversion of native prairie lands to cropland (USGS 2009a).

4.2.1.13.3.1 Dakota Skipper

The Dakota skipper is a candidate for listing under the Endangered Species Act. It is a small to medium-sized butterfly with a 1-inch wingspan. The butterfly inhabits wet lowland prairie dominated by bluestem grasses, and dry upland prairie dominated by mixed bluestem grasses and needle stem grasses. The Dakota Skipper was once widely distributed throughout the northern tallgrass, Dakota mixed grass and a portion of the central tallgrass prairie ecoregions. Its distribution once included tallgrass and mixed grass prairies of Illinois, Iowa, Minnesota, South Dakota, North Dakota, Manitoba and Saskatchewan. The distribution is now largely centered in western Minnesota, northeastern South Dakota and the eastern half of North Dakota; it is unlikely any are in the study area.

4.2.1.13.4 Minnesota State

Based on information available from the Minnesota Department of Natural Resources' Natural Heritage program, 15 Minnesota-listed threatened and endangered species have the potential to occur in Clay County (Appendix F) (MnDNR 2009). These identified state-listed species include eight bird species (six endangered and two threatened species), four invertebrate species (two endangered and two threatened) and three plant species (all threatened). As shown in section 1.9.2 of Appendix F, six of the bird species and all four of the invertebrate species are found in areas with native upland prairies, while the remaining two bird species and the three plant species are found in wetlands, wet meadows, lake shores, and other wet/moist area including peatlands. With their mobility, it can also be assumed that the listed bird and invertebrates may on occasion be sighted in areas adjacent to their preferred habitat.

Minnesota's special concern species that have the potential to occur in Clay County are shown in section of 1.9.1 of Appendix F. As shown, 34 special concern species have the potential to occur in Clay County including two mammal species, five bird species, one reptile species, one fish species, two mussel species, five insect species, and 18 plant species. With the exception of the bald eagle, lake sturgeon and two mussel species, identified species are found in native upland grasslands, savanna and prairies or in wetland areas including wet meadows, fens, swamps, and other wet/moist areas. A recovery program has been initiated to restore lake sturgeon to the Red River drainage, and the two mussel species are found in rivers and streams. Bald eagles frequent riparian areas associated with lakes and large rivers, especially riparian forests that contain large trees that can be used as nest sites, roosts and perches. As discussed above, the mobile species (mammals, birds and insects) can be expected to infrequently occur in areas adjacent to areas that contain habitat preferred by a species.

4.2.1.13.5 Bald Eagles

Bald eagles and their nests are protected from take and disturbance, respectively, per the Bald and Golden Eagle Protection Act. The Fish and Wildlife Service verified the location of two bald eagle nests within the study area. One of the nests is located along the Sheyenne River on the northwest edge of the city of Fargo. This nest was verified to be a successful active nest during the 2009 nesting period. The other nest is located near the confluence of the Sheyenne River and Red River. It is unknown whether this nest was active during the 2009 nesting period.

4.2.1.14 Prime and Unique Farmland

The Federal Farmland Protection Policy Act (FPPA) was enacted in 1981 (Public Law [PL] 98-98) to minimize the unnecessary conversion of farmland to nonagricultural uses as a result of federal actions. In addition, FPPA seeks to assure federal programs are administered in a manner compatible with state and local policies and programs that have been developed to protect farmland.

The policy of the Natural Resources Conservation Service (NRCS) is to protect significant agricultural lands from conversions that are irreversible and result in the loss of an essential food and environmental resource. Prime farmland has been identified by NRCS as a significant agricultural resource that warrants protection. The FPPA defines prime farmland as land that has the physical and chemical characteristics for producing food, feed, fiber, forage and oilseed crops, and is available for these uses. Prime farmland has the soil quality, growing season and moisture supply needed to economically produce sustained high yields of crops when treated and managed, including water management, according to acceptable farming methods.

Three of the Cass County, North Dakota soils are considered prime farmland by the NRCS. Eight other soils are considered prime farmland if they are drained. For the North Dakota alternatives (LPP and ND35K) over 90 percent of the land in the footprint area is considered to be prime and unique farmland; this equates to up to approximately 5,889 acres for the ND35K and 6,878 acres for the LPP.

For the Clay County, Minnesota study area, four soils are considered prime farmland by the NRCS and five are considered prime farmland if they are drained. One soil type is prime farmland if protected from flooding or not frequently flooded during the growing season. One soil type is considered farmland of state importance. For the FCP footprint area over 95 percent of the land is considered to be prime and unique farmland; this equates to approximately 6,540 acres.

The staging area of the LPP was not analyzed for prime and unique farmland because these lands should not be removed from production.

4.2.2 Cultural Resources

4.2.2.1 Historic Conditions

Paleoindian tradition cultures based on the hunting of large Late Pleistocene/early Holocene game animals dating to 11,500 B.P. (years before present) are the earliest documented cultures in North America. No early Paleoindian sites are expected in the study area due to the presence of glacial Lake Agassiz in what is now the Red River valley and northwestern Minnesota. The Sheyenne River valley to the west was a glacial meltwater channel which emptied into the lake until ca. 10,900 B.P. By 10,000 B.P., however, areas of boreal forest surrounding Lake Agassiz and the lake's beaches would have become increasingly available for use by Paleoindian peoples. Small seasonal camps, kill sites and isolated projectile points from Late Paleoindian times have been found on the Lake Agassiz beach ridges and buried in the river terraces in the Red River Basin (USACE 1998).

Glacial Lake Agassiz had receded well north into Canada by 8,000 B.P. and the large Pleistocene mammals (mammoth, camel, horse, bison) hunted by the earlier Paleoindians had become extinct. The boreal forest of the Red River valley was replaced by prairie grassland to the west of the Red River and first by pine and then by mixed deciduous forests to the east of the Red. By 7,000 B.P., the climate had entered a long, dry period during which prairie grasslands spread eastward as far as northeastern Minnesota. The prairie/forest border shifted several times through the subsequent years, but the Red River valley remained prairie grasslands. The expansion of the prairie grassland eastward resulted in a change to more regionally oriented cultures that are part of the Archaic tradition (8,000-3,000 B.P.), based on gathering wild plants and hunting bison and smaller animals. Prairie Archaic cultures were adapted to the tall grass prairie of western Minnesota, while Plains Archaic cultures were adapted to the mixed grass prairie of eastern North Dakota. Archaic sites have been found along small streams, at pothole lakes, on the beach ridges of glacial Lake Agassiz, and buried on the terraces and floodplain of the Red River and its tributaries (USACE 1998).

The following Woodland tradition (3,000-900 B.P.) is characterized by the initial appearance and manufacture of grit-tempered pottery vessels and the use of earthen mounds for burial purposes. Bison hunting and plant gathering formed the basic Woodland economy. The bow and arrow with its small triangular points were introduced at this time. Woodland sites have been found near lakes and rivers and on the uplands overlooking river valleys. Late Prehistoric Period Woodland hunting and gathering cultures continued from 1,100 B.P. (A.D. 900) up to the time of contact (A.D. 1660 in Minnesota; A.D. 1738 in North Dakota) in all but the southernmost Red River valley. Village sites of the Northeastern Plains Village complex occur on river terraces along the Sheyenne River, while Cambria complex village sites occur on river terraces in southwestern Minnesota. Both complexes are based on a dual corn horticulture and bison hunting, wild-plant gathering economy (USACE 1998).

Native American groups known to have lived in the Red River valley include the Hidatsa, Arapaho/Atsina, Plains Ojibwe (Chippewa), Assiniboin, and Yanktonai Dakota. The Arapaho/Atsina are believed to have occupied the Red River valley prior to and during the early 1600s though no archeological sites found to date have been attributed to them. The village-dwelling Hidatsa originated in southwestern Minnesota and migrated northward down the west side of the Red River. Their home territory prior to A.D. 1650 centered on Devils Lake, but extended from the Red River west to the Souris River. They left the Red River-Devils Lake area for the Missouri River valley when the gun-equipped, bison-hunting Plains Ojibwe moved into northeastern North Dakota from northern Minnesota and southern Manitoba in the 1700s. The Plains Ojibwe occupied tipi camps from the Red River west to the Turtle Mountains and hunted bison out on the Plains even prior to their acquisition of the horse (USACE 1998).

The Yankton and Yanktonai Dakota lived in central Minnesota in the mid-1600s where they practiced a hunting-gathering-gardening lifestyle. The Assiniboin, having gradually split off from the Dakota, occupied northwestern Minnesota and the Red River valley in Canada at that time. The prehistoric and protohistoric Blackduck culture in northern Minnesota is considered ancestral to the Assiniboin. The encroachment of the Ojibwe from the north and east between A.D 1679 and 1750 forced both the Dakota and Assiniboin westward. After 1750 the Yanktonai Dakota occupied the southeastern quarter of North Dakota east of the Missouri River. The Assiniboin moved to northwestern North Dakota and adjacent Canada west of the Souris River loop (USACE 1998).

The fur trade flourished in the Red River valley from 1738 to around 1860. French fur trade activities lasted from their initial contact with the Dakota in Minnesota in A.D. 1660 to their 1763 loss of the French and Indian War, and thereby Canada, to the British. From A.D. 1763 to 1803, the British controlled the fur trade in the Red River Basin. Posts were established at Pembina in 1797 by Chaboillez and by David Thompson and Alexander Henry for trade with the Plains Ojibwe in the Red River valley. Independent British trader Robert Dickson established a post at Lake Traverse in the 1790s. Furthermore, a North West Company fur trading post was established at Grand Forks/East Grand Forks in the early 1800s. In 1811, the Scottish Earl of Selkirk, with a land grant from the Hudson's Bay Company, started an agricultural colony at the confluence of the Red and Assiniboine rivers in Manitoba. In 1816 the colony was attacked by the large Metis population of the area. Subsequent to this, Lord Selkirk purchased from the

Ojibwe and Cree a strip of land extending from the mouth of the Red River upstream to where Grand Forks is now located, with the main settlement at the 49th parallel in the Pembina area (USACE 1998).

The development of the Red River oxcart trails was a direct result of the fur trade and the need for transporting goods between settlers in the Red River region and St. Paul, Minnesota. These cart trails were used from the 1830s to 1871 when the railroads replaced them. The Red River Trail followed the east side of the river from Lake Traverse to Pembina. The North Dakota Trail ran north-south to the west of, and roughly paralleling the Red River (USACE 1998). A branch of the Red River Trail crossed the
Red River between these two trails at Georgetown, roughly 12 miles north of Moorhead (Gilman et al. 1979).

A land cession treaty between the United States government and the Ojibwe in 1863 resulted in the Ojibwe giving up most of their land and mineral rights in northern Minnesota and the Red River valley in North Dakota. The Dakota ceded most of their lands in southwestern Minnesota and the Red River Basin in North Dakota in 1872 (USACE 1998).

Minnesota was organized as a territory in 1849 and the Dakota Territory was organized in 1861. Minnesota statehood came in 1858. North and South Dakota became states in 1889 (USACE 1998). Clay County, Minnesota was established in 1862 and Cass County, North Dakota in 1872. Both, Fargo's and Moorhead's origins date to 1871 with the Northern Pacific Railway's arrival at and first crossing of the Red River into North Dakota (Upham 1969:117; Williams 1966:63). Fargo acquired a post office that same year and soon became the hub for a large agricultural area. Fargo was incorporated in 1875 (Williams 1966:63-64) and Moorhead in 1881 (Upham 1969:117). The Northern Pacific Railway built a siding spur, water station and stockyards on the west side of Fargo in the 1870s. In 1882, the spur was extended five miles west and the stockyards and water station were moved to the east bank of the Sheyenne River. The rail station, originally named Haggert, was renamed West Fargo in 1925 when a company town grew up around the newly established Armour meat packing plant. West Fargo was incorporated in 1931 and is now a suburb of Fargo (Williams 1966:72-73).

Settlement of western Minnesota and the Dakotas was directly tied to the arrival of the Northern Pacific Railroad in Moorhead in 1871 and the St. Paul, Minneapolis and Manitoba (Great Northern) Railroad in Grand Forks in 1880. The 1878-1887 influx of settlers from Germany, Scandinavia, Great Britain, Ireland and the Great Lakes region into the Red River valley was the direct result of the chance for free land under the Homestead Act of 1862 and the active promotions of the railroads. A second influx of settlers occurred from the late 1890s to 1920 and involved eastern, central and southern Europeans. Improvements to highways and country roads occurred after 1910 with the increasingly common use of the automobile. The drought and depression of the late 1920s and 1930s resulted in the loss of many farms in the Red River valley due to an inability to pay mortgages and/or taxes because of successive crop failures (USACE 1998).

4.2.2.2 Previous Cultural Resources Investigations
Due to the large study area the information gathered from previous cultural resources investigations was limited for each of the diversion channel alternatives as described below.

The diversion channel alignments for the North Dakota alternatives (LPP and ND35K) substantially overlap. Information gathered was limited to a one-mile corridor centered on the overlapping alignments. The previous investigations include a 1978 survey of parts of the lower Sheyenne River Basin (Vehik 1978); a 1986 survey of the West Fargo Flood Control Project (Floodman 1988); a 1986 archeological survey and test excavations in Cass County (Michlovic 1986); a 1990 Cenex pipeline survey (Schweigert 1990); and the 2009 survey of the Fargo Southside Study Area (URS Group 2009). Generally less than ten percent of the North Dakota diversion channel alignment has been covered by these prior cultural resources surveys, the exception is where it intersects the existing West Fargo diversion channel area, which has been completely investigated. Until 2010, there have been no previous cultural resource surveys along a one-eighth-mile wide corridor centered on the LPP and ND35K plan tie-back levee alignments, which are located in Minnesota.

Previous Phase I cultural resources investigations within the one-mile-wide corridor centered on the FCP diversion channel alignment includes a 1978 archeological survey along the Red River in Clay County, Minnesota (Michlovic 1978, 1979). A historic standing structures inventory of the city of Moorhead took place in 1979 (Moorhead Community Development Department 1979). Less than five percent of the alignment has been previously checked for cultural resources. Until 2010, there have been no previous cultural resources surveys within the one-half mile wide corridor centered on the FCP Red River Breakout Channel and Wild Rice River Breakout Channel alignments, located in Minnesota and North Dakota, respectively. The 2009 Phase I cultural resources survey of the Fargo Southside Study Area (URS Group 2009) includes small areas of the one-eighth-mile wide corridor centered on the FCP's tie-back levee alignment, which is located primarily in North Dakota.

A Phase I cultural resources survey of the ND35K alignment and the FCP alignment (including its tie-back levee and breakout channel alignments) was begun in 2010. This survey includes portions of the LPP diversion channel and tie-back levee alignments as it overlaps substantially with the same features of the ND35K alternative.

4.2.2.3 Known Cultural Resources Sites
Cultural resources include any prehistoric or historic archeological site, building, standing structure or object at least 50 years old relating to the history, architecture, archeology or culture of an area. A historic property is a site, structure, building, object or district which has been listed on or has been determined eligible for inclusion on the National Register of Historic Places. An unverified site lead refers to a potential prehistoric or historic archeological site based on verbal or written information which has not been field verified by a professionally qualified archeologist or historian.

Known cultural resources within the one-mile corridor centered on the ND35K diversion channel alignment include four prehistoric archeological sites (32CS42, 32CS43, 32CS44, 32CS201), six historic archeological sites (FM1-2, FM2-2, FM2-5, FM2-6, FM2-7, FM4-7), one prehistoric isolated find (FM2-8), three bridges (32CS4461, 32CS4462, ND-15), 11 farmsteads (ND-1 to ND-7, ND-10 to ND-14), three houses (32CS5090, 32CS5091, ND-9), one railroad crossing (ND-8), a collapsed granary (ND-16), and a collapsed house (ND-17). In addition, there is an unverified lead to one historic archeological site (32CSX238b-Red River Trail segment). As of March 8, 2011, there are no historic properties along the ND35K diversion channel alignment listed in the National Register of Historic Places. The only property determined eligible for the National Register is the Sheyenne River Bridge in Warren Township (32CS4462). One historic archeological site (FM2-2) and two farmsteads (ND-5, ND-14) are recommended as eligible to the National Register. Phase II testing to evaluate the National Register of Historic Places eligibility of archeological sites 32CS42 and 32CS44 for the West Fargo Flood Control Project resulted in non-eligibility determinations (Persinger 1988).

An unverified lead to one historic archeological site (21CYr), the Red River Trail, three historic isolated finds (FM3-3, FM3-4, FM3-6), one historic archeological site (FM3-2), and a segment of railroad (FM3-5) are the only known cultural resources within the one-eighth-mile wide corridor centered on the ND35K tie-back levee centerline. The tie-back levee centerline crosses the historic oxcart trail in one location in Clay County, Minnesota. The railroad segment has been recommended as eligible to the National Register. No National Register listed historic properties were present along this alignment as of March 8, 2011.

Known cultural resources within the one-mile-wide corridor centered on the FCP diversion channel alignment include three prehistoric archeological sites (21CY3, 21CY19, 21CY55), three isolated prehistoric artifacts (FM2-3, FM2-12, FM4-6), five historic archeological sites (FM1-1, FM2-1, FM2-4, FM2-9, FM2-11), 11 farmsteads (MN-2 to MN-6, MN-13 to MN-17), six historic houses (CY-KRG-001-John Olness House at Kragnes, MN-7, MN-9 to MN-12) and four other historic standing structures (CY-DWG-003 and MN-8 -Northern Pacific shop buildings at Dilworth, CY-KRG-004-Kragnes Bar, CY-KRG-005-warehouse at Kragnes). The FCP diversion channel alignment crosses the unverified location of three historic archeological sites: the ghost towns of Ruthruff (21CYk) and Lafayette (21CYl[el]), and the Red River Trail (21CYr). The latter historic oxcart trail is crossed three times by this diversion's centerline. The FCP diversion channel alignment also crosses the unverified historic archeological ghost town site of Burlington (21CYo). The John Olness House (CY-KRG-001) at Kragnes is the only National Register listed property found along the FCP diversion channel alignment as of March 8, 2011. Historic archeological site FM2-4 and farmstead MN-14 are recommended as eligible to the National Register.

There are unverified leads to two historic archeological sites within the one-half-mile wide corridor centered on the FCP Red River Breakout Channel alignment: the ghost town of Burlington (21CYo) and the Red River Trail (21CYr). The breakout channel centerline follows the historic oxcart trail for three-quarters of a mile. One historic archeological site (FM4-4) and two farmsteads (MN-18, MN-19) are also located along this alignment. Farmstead MN-19 is recommended as eligible to the National Register. No National Register listed historic properties are present along this alignment as of March 8, 2011.

There is an unverified lead to one historic archeological site within the one-eighth-mile wide corridor centered on the FCP tie-back levee alignment: the Holy Cross Mission (32CSX1). One prehistoric and historic archeological site (FM4-3), the Meridian Highway (322CS2657), and one farmstead (ND-11) are also located along this alignment. The archeological site is recommended as eligible to the National Register. No National Register listed historic properties are located along this alignment as of March 8, 2011.

There is one historic archeological site (FM-A) within the one-half-mile wide Wild Rice River breakout channel alignment, which is part of the FCP. This site is been recommended as eligible to the National Register. No National Register listed historic properties are located along this alignment as of March 8, 2011.

Known cultural resources sites within the one-mile-wide corridor centered on the LPP diversion channel alignment include five prehistoric archeological sites (32CS42, 32CS43, 32CS44, 32CS4563), one prehistoric isolated find (FM2-8), eight historic archeological sites (32CS5078, FM1-2, FM2-2, FM2-5, FM2-6, FM2-7, FM4-1, FM4-7), three historic archeological site leads (32CSX33, 32CSX131, 32CSX238b), one church (32CS114), two bridges (32CS4462, ND-15), 13 farmsteads (ND-1 to ND-7, ND-10 to ND-14), one railroad segment (ND-8), one historic house (ND-9), one collapsed granary (ND-16), and one collapsed house (ND-17). No National Register of Historic Places listed historic properties are present along this alignment as of March 8, 2011. Bridge site 32CS4462 has been determined eligible to the National Register and historic archeological site FM2-2 and farmsteads ND-5 and ND-14 are recommended as eligible to the National Register. Archeological sites 32CS42 and 32CS44 were determined not eligible to the National Register in 1988 in connection with the Horace-West Fargo Flood Control Project.

One historic archeological site (FM3-2), three historic isolated finds (FM3-3, FM3-4, FM3-6), and a segment of railroad (FM3-6) are located along the LPP's one-eight-mile wide diversion tie-back levee alignment in Minnesota. The railroad segment is recommended as eligible to the National Register. There are no National Register listed historic properties along this alignment as of March 8, 2011.

There is one farmstead (ND-11) located in Storage Area #1 for the LPP and within one-eighth-mile of its exterior boundary. There are no National Register listed or eligible historic properties in Storage Area #1 as of March 8, 2011.

There are no recorded cultural resources sites at the staging area tie-back levee alignment associated with the LPP alternative. There are no National Register listed or eligible historic properties along this alignment as of March 8, 2011.

Cultural resources sites within the staging area will be investigated, evaluated, and mitigated in accordance with the Programmatic Agreement between the Corps, the Minnesota State Historic Preservation Officer, and the North Dakota State Preservation Officer (Attachment 3). If a property is flooded with existing conditions, any impact from the LPP alternative is expected to be minimal.

4.2.2.4 Cemeteries

Based on the U.S.G.S. 7.5' topographic quadrangles, there are no cemeteries within one-half mile of either side of the FCP diversion channel centerline and within one-quarter mile of either side of the centerlines of the associated Red River breakout channel and Wild Rice River breakout channel. There are two cemeteries within one-quarter mile of the associated tieback levee in North Dakota. The Holy Cross Cemetery in the SE-SE-NE, Section 13, Township 138 North, Range 49 West, Cass County, is approximately 460 feet (0.08 mile) north of the tieback levee centerline. The St. Benedict Church Cemetery in the SW-SE-SE-NE, Section 34, Township 138 North, Range 49 West, Cass County, is approximately 623 feet (0.12 mile) north of the tieback levee.

Based on the U.S.G.S. 7.5' topographic quadrangles, there are no cemeteries within one-half mile of either side of the ND35K diversion channel centerline and associated tieback levee centerline in Minnesota.

There are no cemeteries within the LPP diversion channel alignment, its tieback levee in Minnesota, the County Road 17 tieback levee, or Storage Area #1. The St. Benedict Church Cemetery (C656) is located approximately 130 feet east of Storage Area #1 in the SW-SE-SE-NE, Section 34, Township 138 North, Range 34 West, Cass County, North Dakota. There are twelve cemeteries in the upstream staging area: eight in North Dakota (North Pleasant Cemetery, Hemnes Cemetery, South Pleasant Cemetery, Christine Cemetery, Pioneer Cemetery, Eagle Cemetery, Schmitt Cemetery, and Smith Cemetery) and four in Minnesota (Hoff Cemetery, Clara Cemetery, Comstock Cemetery, and Wolverton City Cemetery). Details on these cemeteries given in Table 5 below are based on information from U.S.G.S. 7.5' topographic quadrangles, the North Dakota Department of Health's Cemetery Listing for Cass and Richland Counties (accessed May 23, 2011), and MapQuest 2010 air photo imagery (accessed 30 June 2011). The Eagle Cemetery (C448) is listed as being in the NW corner SW1/4 NW1/4 of 18-136-48. This legal location actually applies to the Pioneer Cemetery (per U.S.G.S. 7.5' Christine quad, 1959, Photo revised 1979). The Eagle Cemetery is located in the SW-SW-NW-SW and NW-NW-SW-SW of Section 20, T136N, R48W on that same quadrangle. The Evangelical Christian Church (ECC) Cemetery (C459) is listed in the Cemetery Listing as being in Section 19, Township 136 North, Range 48 West, but there is no cemetery visible in the 2010 air photo of Section 19. The church itself is located in the SW-SW-SW of Section 20. The ECC Cemetery may be the same as the Eagle Cemetery just to the north of the church lot in Section 20.

Table 34 - Cemeteries in the upstream staging area with 1-percent chance event depth of water difference with the project in place.

CEMETERY NAME	CEMETERY NUMBER	TOWNSHIP and RANGE	SEC-TION	QUARTER-QUARTER	ACRES (approx.)	ADDL FT WATER DEPTH W/PROJ
Cass County, ND						
North Pleasant	C821	T137N, R49W	27	S-SE-SW	1	1.01-3.00

Richland Co., ND						
Hemnes	C1177	T136N, R49W	1	NE-NW-NW-SE	0.20	0.30-3.00
South Pleasant	C453	T136N, R49W	22	NE-NE-NE-NW	0.25	0.05-0.30
Christine	C469	T136N, R49W	26	W-NW-NW-NE	0.25	0.30-1.00
Pioneer	C448?	T136N, R48W	18	NW-NW-SW-NW	0.10	0.00
Evangelical Christian Church (same as Eagle Cemetery ?)	C459	T136N, R48W	19	No cemetery in Section 19; church in Section 20, SW-SW-SW		0.00-3.00 in Section 19; 0.00 at church
Eagle	C448?/C459?	T136N, R48W	20	SW-SW-NW-SW and NW-NW-SW-SW	0.60	0.00-3.00
Schmitt	C435	T135N, R48W	8	C-N-N-SW-SE	0.10	0.00
Smith	C5055 (not registered)	T135N, R48W	20	? (on farmstead)	100 sq.ft.	0.00-0.30
Clay County, MN						
Hoff		T137N, R48W	9	SW-SW-SW-SW	0.40	3.01-9.35
Clara		T137N, R48W	17	SW-SW-SW-SW	0.60	3.01-9.35
Comstock		T137N, R48W	28	NE-NE-NE-NE	0.60	0.30-3.00
Wilkin Co., MN						
Wolverton City		T136N, R48W	28	SW-SW-SW-NW	0.50	0.00

4.2.3 Socioeconomic Resources

This section presents an overview of major socioeconomic characteristics and trends, including demographics and economics in order to provide a context from which to assess impacts of the proposed project and alternatives. The affected environment extends along the Red River, between Abercrombie, ND, and the Canadian border. It includes portions of 12 counties in North Dakota and Minnesota and the Fargo-Moorhead Metropolitan Statistical Area (MSA). The MSA covers portions of Cass County, ND, and Clay County, MN. Quantitative data reported by the U.S. Census Bureau were utilized to analyze the socio-demographic characteristics of the MSA. The dataset used for the analysis includes the 3-year estimates (2006, 2007 and 2008; pooled data) from the Population and Housing Narrative Profile of the American Community Survey (ACS). These ACS data provide the highest-quality, most general current data on the Fargo-Moorhead area. Data to report population growth is from annual population estimates produced by the Census Bureau.

4.2.3.1 Existing and Future Without Project Flood Damage Risk

Hydrologic and hydraulic (H&H) modeling was performed throughout the affected area for the Red River of the North and tributaries at three points in time: existing conditions, 25 years out and 50 years out. Economic conditions were inventoried for existing conditions and forecasted for the future analysis years. Flood damage categories include damage to infrastructure, and emergency flood fighting costs. Consideration was given to existing levees and other flood risk management projects, and sewer backup flooding. The H&H and economic inventories formed the basis for evaluating flood damage risk in the study area.
Table 35 displays existing conditions expected annual damages and equivalent expected annual damage.

Table 35 - Existing and Future without Project Conditions Damages

Existing Conditions Expected Annual Damage			
	Infrastructure	Emergency Costs	Total
Fargo-Moorhead Metro	$190,800	$7,700	$198,500
Upstream of Fargo-Moorhead to Abercrombie	$690	-	$690
Downstream of Fargo-Moorhead to Thompson	$760	-	$760
Equivalent Expected Annual Damage (Including Future without Project Conditions)			
	Infrastructure	Emergency Costs	
Fargo-Moorhead Metro	$187,700	$7,100.00	$194,800
Upstream of Fargo-Moorhead to Abercrombie	$690	-	$690
Downstream of Fargo-Moorhead to Thompson	$760	-	$760

*Figures in $1,000's

4.2.3.2 Regional Economy

The Fargo-Moorhead Metropolitan Statistical Area (MSA) straddles the North Dakota and Minnesota border on either side of the Red River. Fargo-Moorhead's business environment continues to grow and is ranked as follows, according to the Greater Fargo-Moorhead Economic Development Corporation (GFMEDC) Web site (2009):

- #5 in Forbes ranking of the Top College Towns for Jobs in May 2009.
- #7 in Forbes Best Places for Business and Careers in March 2009. This is the sixth consecutive year that Fargo has made the top ten for small metropolitan areas. The index ranks cities according to cost of doing business, educational attainment of the population, income growth, projected job growth and net migration.
- #1 city in North Dakota for entrepreneurial start ups, according to Business Week.
- #8 in MSN and CareerBuilder.com's October 2008 list of the 25 Best Markets to Find a Job.

With one of the lowest unemployment rates in the nation, Fargo-Moorhead has experienced gains in income and employment for the last 5 years that exceed the national average. Also, according to Moody's Economy.com, the Fargo-Moorhead economy continues to rank among the highest in vitality for U.S. metropolitan areas (GFMEDC 2009).

The Fargo-Moorhead MSA unemployment rate in October 2009 was 3.5 percent, which had increased from 1.6 percent in October 2000 despite seasonal fluctuations (Job Service North Dakota 2010). However, the unemployment rate in March 2009 hit a 10-year high at 5.1 percent.

Historically, the economy in Fargo-Moorhead has been dependent upon agriculture; however, that has changed substantially in recent decades. Now, the economy is based on retail trade, healthcare, technology, higher education and manufacturing. Major employers in the Fargo-Moorhead MSA are in the healthcare and education industries. Among the companies with the largest number of full-time employees (FTEs), the top five are in one of these two industries. MeritCare Health Systems is the largest employer with 3,691 FTEs (GFMEDC 2010). North Dakota State University is the second-largest with 2,401 FTEs. Notable mentions in other industries, such as back office operations, are the US Bank Service Center with 952 FTEs, and in the technology industry, Microsoft with 948 FTEs.

4.2.3.3 Population size and composition

According to the 2009 ACS, the population of the Fargo-Moorhead metropolitan area is estimated to be 194,839 persons. Based on the 2010 census, the total population in the 12-county study area is estimated to be 377,631 persons (U.S. Census Bureau, 2010 Census). As reported by the 2009 ACS estimates, the gender ratio within the metro area is nearly 1:1 (50 percent male and 50 percent female) and the median age is 30.2 years. Nationally, the population is 51 percent female and the median age is 36.7 years. Persons under 18 years old represent 23 percent of the population, which is lower than the national percentage of 25 percent. The percentage of residents over the age of 65 years (10.2 percent) is also lower in the metro area than the national percentage of 13 percent (U.S. Census Bureau, 2009 ACS). The communities downstream of the metro area have lower percentages of persons under 5 years old, but higher concentrations of persons over 65 years old. It can generally be said of the downstream communities that, on average, they have a slightly higher percentage of older persons than is found in the metro area.

With the exception of Clay County, MN and Polk County, MN, and Grand Forks and Cass Counties, ND, all the other counties in the study area experienced a decline in population between 2000 and 2010. The decreases ranged from 4.4 percent to as much as 16.1 percent. Over the past 50 years, the communities downstream of the Fargo-Moorhead metro area have seen population losses of between 10 and 35 percent. The population of nearly every city and township between Fargo-Moorhead and Thompson, ND has decreased, with the exception of Oakport and Kragnes Townships, which are located immediately downstream of the metro area (U.S Census Bureau, 2000).

4.2.3.4 Household structure

The ACS estimates from 2009 indicate that the average size of the 84,330 households in the metro area is 2.3 persons, compared to an average size of 2.6 persons nationally. In 2000, there were nearly 70,000 households in the metro area and a total of 128,262 households in the 12-county study area (U.S. Census Bureau, 2000 Census). In the metro area, more than half (58 percent) of these households consisted of families (46 percent married couples and 12 percent other). The majority of nonfamily households consisted of persons living alone, which represented 32 percent of all households. The percentage of married-couple families closely mirrored ACS estimates for the United States as a whole (50 percent); the percentage of households of persons living alone was higher than the estimate for the United States (27 percent); and the percentage of other nonfamily households in the United States was correspondingly lower (6 percent nationally).

4.2.3.5 Race and ethnic diversity

While ethnic diversity in the metro area stands markedly lower than that in the United States as a whole, there seems to be an upward trend in the ratio of non-White residents to White residents. Between 2000 and 2010, nearly all the counties in the study area reported an increase in their share of minority persons. While an estimated 13 percent of U.S. residents were foreign-born in 2006 through 2008, only 4 percent of persons living in the metro area during that period were foreign-born (U.S. Census Bureau, 2009 ACS) . Between 2000 and 2005, immigrants accounted for 54 percent of the Fargo-Moorhead metro area's growth. The universities in the Fargo-Moorhead metro area also attract a foreign student population, adding to its diversity. Table 36 and Table 37 show the racial and ethnic characteristics of the North Dakota and Minnesota counties, from upstream to downstream based on the latest 2010 Census.

Table 36 - Population Characteristics of Study Areas–North Dakota

Race	North Dakota											
	Richland County		Cass County		Traill County		Grand Forks County		Walsh County		Pembina County	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
White	15,507	95.0%	137,308	91.7%	7,809	96.2%	60,358	90.3%	10,391	93.5%	7,077	95.5%
Non-Hispanic White	15,351	94.1%	135,530	90.5%	7,693	94.7%	59,271	88.6%	9,834	88.4%	6,947	93.7%
Hispanic White	156	1.0%	1,778	1.2%	116	1.4%	1,087	1.6%	557	5.0%	130	1.8%
Non-White	814	5.0%	12,470	8.3%	312	3.8%	6,503	9.7%	728	6.5%	336	4.5%
Black or African American alone	110	0.7%	3,428	2.3%	42	0.5%	1,361	2.0%	25	0.2%	21	0.3%
American Indian and Alaska Native alone	330	2.0%	1,827	1.2%	64	0.8%	1,657	2.5%	168	1.5%	144	1.9%
Asian alone	88	0.5%	3,532	2.4%	21	0.3%	1,292	1.9%	36	0.3%	11	0.1%
Native Hawaiian and Other Pacific Islander alone	9	0.1%	52	0.0%	1	0.0%	40	0.1%	4	0.0%	2	0.0%
Some other race alone	67	0.4%	798	0.5%	89	1.1%	553	0.8%	345	3.1%	58	0.8%
Two or more races	210	1.3%	2,833	1.9%	95	1.2%	1,600	2.4%	150	1.3%	100	1.3%
Total	16,321	100.0%	149,778	100.0%	8,121	100.0%	66,861	100.0%	11,119	100.0%	7,413	100.0%
Minority Population	970	5.9%	14,248	9.5%	428	5.3%	7,590	11.4%	1,285	11.6%	466	6.3%

Source: U.S. Department of Commerce, U.S. Census Bureau, 2010. SF1 and SF3 Tables.

Table 37 - Population Characteristics of Study Areas–Minnesota

Race	Minnesota											
	Wilkin County		Clay County		Norman County		Polk County		Marshall County		Kittson County	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
White	6,381	97.0%	54,684	92.7%	6,455	94.2%	29,495	93.3%	9,119	96.6%	4,484	98.5%
Non-Hispanic White	6,294	95.7%	53,434	90.6%	6,293	91.8%	28,497	90.2%	8,952	94.8%	4,434	97.4%
Hispanic White	87	1.3%	1,250	2.1%	162	2.4%	998	3.2%	167	1.8%	50	1.1%
Non-White	195	3.0%	4,315	7.3%	397	5.8%	2,105	6.7%	320	3.4%	68	1.5%
Black or African American alone	15	0.2%	842	1.4%	13	0.2%	270	0.9%	26	0.3%	11	0.2%
American Indian and Alaska Native alone	64	1.0%	803	1.4%	109	1.6%	453	1.4%	43	0.5%	4	0.1%
Asian alone	18	0.3%	846	1.4%	25	0.4%	218	0.7%	19	0.2%	16	0.4%
Native Hawaiian and Other Pacific Islander alone	0	0.0%	21	0.0%	0	0.0%	2	0.0%	3	0.0%	0	0.0%
Some other race alone	27	0.4%	528	0.9%	92	1.3%	497	1.6%	148	1.6%	12	0.3%
Two or more races	71	1.1%	1,275	2.2%	158	2.3%	665	2.1%	81	0.9%	25	0.5%
Total	6,576	100.0%	58,999	100.0%	6,852	100.0%	31,600	100.0%	9,439	100.0%	4,552	100.0%
Minority Population	282	4.3%	5,565	9.4%	559	8.2%	3,103	9.8%	487	5.2%	118	2.6%

Source: U.S. Department of Commerce, U.S. Census Bureau, 2010. SF1 and SF3 Tables.

Based on 2010 U.S. Census data, downstream communities in both North Dakota and Minnesota had smaller minority populations than Cass County, ND and Clay County, MN with the exceptions being Grand Forks County, ND and Polk County, MN (U.S. Census Bureau, 2010 Census). As reported by the 2010 U.S. Census, the Hispanic/Latino population downstream of Fargo represents 2.4 percent of the entire population. Within Moorhead, Hispanic persons account for 4.5 percent of the total population. As reported by the 2000 U.S. Census, comparing the populations that "speak English less than 'very well, '" finds larger non-English proficient populations in Fargo and Moorhead than in their respective downstream communities (U.S. Census Bureau, 2000). In North Dakota, the non-English proficient population downstream is 4.5 percent smaller, on average, than in Fargo. In Minnesota, the difference between the downstream communities and Moorhead is 6.4 percent (U.S. Census Bureau, 2000).
The percentage of residents who speak a language other than English at home was markedly lower in the Fargo-Moorhead metro area than in the United States as a whole (20 percent of persons more than 5 years old nationally vs. 6 percent in the metro area). Approximately one-third of these persons speak Spanish (U.S. Census Bureau, 2009 ACS).

4.2.3.6 Education

According to the 2000 census, 39 percent of the population in the Fargo-Moorhead metro area had an associate degree or higher (compared to 27 percent nationally). In 2009, the percentage of residents in the metro area with an associate degree or higher increased to 45 percent of the population (U.S.

Census Bureau, 2009 ACS). During the same time period, persons with a high school diploma accounted for nearly 26 percent of the population in the metro area compared to 29 percent nationally.

As more recent data on the educational attainment of the population is not available for the all 12 study area counties, data from the 2000 U.S. Census was utilized to better understand the levels of educational attainment. All the downstream study area counties in North Dakota had higher percentage of persons with a high school diploma compared to levels exhibited in Fargo. Similarly, the downstream counties in Minnesota had persons with higher levels of persons with a high school diploma than was found in Moorhead. However, persons with College and Bachelor's degrees were higher in Fargo and Moorhead compared to the downstream counties in their respective states. Table 38 and Table 39 show the levels of educational attainment in the study area counties in North Dakota and Minnesota.

Table 38 - Educational Attainment in Study Areas–North Dakota

Geographic Area	High School Graduates (age 25+)	College Graduates (age 25+)
North Dakota	27.9%	24.5%
Cass County	22.9%	26.9%
Pembina County	31.9%	24.0%
Walsh County	32.1%	24.2%
Grand Forks County	24.4%	27.7%
Traill County	25.9%	27.4%
Richland County	27.4%	25.0%

Source: U.S. Department of Commerce, U.S. Census Bureau, 2000.

Table 39 - Educational Attainment in Study Areas–Minnesota

Geographic Area	High School Graduates (age 25+)	College Graduates (age 25+)
Minnesota	28.8%	24.0%
Clay County	28.2%	25.4%
Kittson County	34.5%	22.9%
Marshall County	37.0%	21.5%
Polk County	31.7%	23.9%
Norman County	34.9%	24.9%
Wilkin County	32.5%	23.5%

Source: U.S. Department of Commerce, U.S. Census Bureau, 2000.

4.2.3.7 Housing

In 2009 (U.S. Census Bureau, 2009 ACS) there were 87,115 occupied housing units in the metro area, compared to 73,356 in 2000 (U.S. Census Bureau, 2000 Census). Nearly six percent of the housing units stood vacant (much lower than the national average of 12 percent), 58 percent were single-unit structures, 39 percent were multi-unit structures, and 3 percent were mobile homes. The median value of owner-occupied housing units was $142, 800. Table 40 shows the housing data for the study area (U.S. Census Bureau, 2009 ACS).

Table 40 - Housing Data in the Study Area

Geographic Area	Housing Units	Percent of Occupied Housing Units
North Dakota	309,043	88.3%
Cass County	64,139	95.2%
Pembina County	4,067	83.3%
Walsh County	5,739	85.1%
Grand Forks County	29,304	91.5%
Traill County	3,760	89.5%
Richland County	7,695	86.8%
Minnesota	2,301,307	89.6%
Clay County	22,976	92.7%
Kittson County	2,738	75.5%
Marshall County	4,885	85.4%
Polk County	14,677	85.2%
Norman County	3,499	84.0%
Wilkin County	3,106	87.0%

Source: U.S. Department of Commerce, U.S. Census Bureau, 2005-2009 American Community Survey 5-Year Estimates.

Based on 2009 estimates (U.S. Census Bureau, 2009 ACS), the median monthly housing cost for mortgaged owners was lower than the comparable national statistic ($1,316 in the metro area and $1,486 nationally). For non-mortgaged owners the cost was $446, which is comparable to the national statistic of $419 and for renters the cost was $597, which is markedly lower than the $817 national statistic. Nearly 14 percent of non-mortgaged owners spent at least 30 percent of their household income on housing, compared to 16 percent nationally; 46 percent of renters (50 percent nationally) fell into this category. More than three-quarters (77.7 percent) of residents lived in the same house they had lived in 1 year before.

4.2.3.8 Journey to work

For commutes to work in Fargo-Moorhead metropolitan area, the proportion of workers who drove alone was somewhat higher than in the United States as a whole (82 percent versus 76 percent nationally), and the proportion who carpooled (9 percent) or used public transportation (1 percent) were somewhat lower. Notably, an estimated 7.1 percent of occupied households had no vehicle available (ACS pooled data from 2006–2008).

The mean travel time to work in all 12 counties in the study area was less than 25 minutes and, with the exception of Marshall and Norman Counties, MN, commute times were less than 20 minutes (U.S. Census Bureau, 2000).

4.2.3.9 City Government

The Fargo City Commission consists of four commissioners and the mayor, who acts as the commission president. Commissioners are elected to four-year terms from the city at large, not from specific precincts. Two commission seats are elected biennially. Each commissioner is responsible for specific portfolios of city departments and projects. Commissioners and mayors are limited to three consecutive four-year terms. The city has 84 full-time fire department personnel, and 83 full-time city police officers.

The city of Moorhead operates under the "city manager" form of government, with an elected City Council serving as decision makers for the community. Their policies focus on long-range goals such as community growth, land use development, capital improvement plans, capital financing and strategic development. The City Manager, who reports directly to the Mayor and the City Council, is responsible for carrying out the established policies and oversees the daily operation of the city of Moorhead.

In Moorhead, the City Manager supervises four departments, each with its own divisions and directors: Community Services, Operations, Fire and Police. The city has 37 full-time fire department personnel, and 55 full-time and 6 part-time city police officers.

4.2.3.10 Recreational Opportunities

The metro area has a number of recreational activities, including ice-skating, figure skating, youth and adult hockey, volleyball, basketball, track, soccer, walking, cross-country skiing, ballroom dancing, table tennis, and broom ball. There are also 39 casinos in public establishments, with profits used for public causes. The area features neighborhood and regional public parks covering over 3,000 acres, 7 public golf courses within Fargo-Moorhead, and soccer and softball/baseball complexes. Biking and walking trails run for more than 99 miles throughout Fargo, Moorhead and West Fargo. There are a number of annual celebrations, including the Fargo Film Festival, Downtown Street Fair, Pioneer Days, Fargo Blues Festival, and Christmas on the Prairie.

Residents of the study area tend to be active in recreational activities. This is evidenced by the numbers that participate in sporting events throughout the year. Many residents are engaged in hunting or fishing. Fargo-Moorhead is a regional hub for the arts, with many local painters, musicians, street fairs, and music venues.

The planning commissions in Fargo and Moorhead aim to increase the "walkability" of their cities and neighborhoods. Participants in Moorhead planning workshops suggested that a park should be within walking distance of all homes and that they would like to see an increase in the connectivity of neighborhoods. The city of Fargo also aims to use smart growth principles to keep the city as compact as possible to limit expensive infrastructure and keep down the cost of energy.

Outside the metro area, numerous parks line the river. Boaters have access to the water from boat ramps on both sides of the river. There are also several shore-fishing facilities. In the unincorporated areas of Clay County, parks and recreation is the second largest land-use category, accounting for 3 percent of the land area. There are five area state parks that provide year-round outdoor recreation activities within a short driving distance of Fargo-Moorhead. Most state parks provide camping, swimming, boating/canoeing, fishing and hiking/biking/snowmobile trails. The cities of Grand Forks and East Grand Forks are about 90 miles from Fargo-Moorhead and offer additional recreation opportunities.

Appendix M, Recreation has additional information on the existing recreational opportunities in the region.

4.2.3.11 Cultural Opportunities
Fargo-Moorhead is home to several art museums, a growing zoo, an active community theater organization, a symphony orchestra and an opera company. The three universities in town host a wide variety of activities ranging from prominent visiting lecturers to internationally-known performing artists. The Fargodome is a 28,000-seat arena adjacent to the North Dakota State University (NDSU) campus and hosts activities ranging from concerts and ice shows to rodeos and monster truck races. Bonanzaville, located in West Fargo, celebrates the region's history through displays and events. The 1926 restored Fargo Theatre is a vintage movie palace with a vaudeville stage. The theatre serves as a multi-purpose facility with capacity for film showings, live productions and meetings, and is a registered historic landmark. It also houses a restored theatre pipe organ, the "Mighty Wurlitzer." The home stadium for the area minor league baseball team, the Fargo Moorhead Redhawks, is located on the NDSU campus. The cities host collegiate athletic events ranging from Division I football to women's basketball. The Fargo Force major junior hockey team plays in the newly constructed Urban Plans Center, which hosted the U-18 World Junior Hockey Championship in April, 2009.

4.2.3.12 Transportation
Transportation planning is done in conjunction with the Fargo-Moorhead Council of Government (Metro COG). Metro COG is the primary transportation planning agency for the metropolitan area. Metro COG coordinates the development of a comprehensive and coordinated transportation system for the area. In addition to roadway networks, Metro COG also works on transit and bicycle routes.

Moorhead has 175 miles in its local street system, of which 156.5 miles, almost 90 percent, are under the City's jurisdiction. Twelve of the remaining miles are under state jurisdiction, of which 6.5 miles are under Clay County's jurisdiction.

Fargo has approximately 552 miles of roadway divided into the following functional classifications: 338 miles of local or residential; 53 miles of local collectors; 77 miles of minor arterial; and 84 miles of principal arterial roadways.

4.2.3.12.1 Major Highways
Fargo Moorhead is connected with northern markets across the United States and Canada via Interstate-94. The I-94/I-90 corridor reaches from Boston and Quebec on the east coast to Seattle on the west coast linking major metropolitan areas, such as Buffalo, N.Y., Cleveland, Detroit, Chicago, Milwaukee, Minneapolis, Montreal and Toronto.

The community is also connected with central markets through the United States via I-29. I-29 reaches from Winnipeg to Kansas City, Missouri, where I-35 continues to the border of Mexico. I-29 also provides direct links to major east-west connections such as I-40, I-70, I-80 and I-90.

4.2.3.12.2 Air Service

Hector International Airport in Fargo is serviced by Delta Airlines, United Airlines, Allegiant Air and American Eagle Airlines with daily jet service to/from Chicago, Salt Lake City, Minneapolis and Denver. Frequent seasonal charter flights are available to points in Nevada and Mexico. Hector also features multiple cargo/freight carriers; six on-site car rental companies; 24-hour full service aviation line services including fueling, aircraft maintenance and avionics repair station; aircraft charter service; flight school; aircraft rental; heated hanger space; and a U.S. Port of Entry with on-site customs services.

4.2.3.12.3 Railroads

Burlington Northern Santa Fe (BNSF) has its Dakota division headquartered in Fargo and serves North Dakota, Northwest South Dakota, Eastern Montana, Western Minnesota and the Canadian province of Manitoba with 60 trains per day. An Intermodal Port operated by Burlington Northern Santa Fe, located 3 miles east of downtown Fargo-Moorhead in Dilworth, MN handles flatcar shipments of trailers, containers, and other freight.

Railroad service is offered to multiple industrial park sites within the Fargo-Moorhead area, providing convenience and efficiency to the businesses using the services. Otter Tail Valley Railroad is a short-line railroad serving industrial parks and rural communities throughout Clay County, MN. The Otter Tail Valley Railroad interchanges with the Burlington Northern Santa Fe Railroad and Dilworth yard in Fargo-Moorhead.

Red River Valley & Western Railroad is a short-line regional railroad serving industrial parks and properties in rural communities throughout Cass County, ND. The Red River Valley & Western interchanges with the Burlington Northern Santa Fe Railroad in Casselton, ND and with the Canadian Pacific Railroad just west of Cass County.

Amtrak provides service to the Fargo-Moorhead area with its Chicago - St. Paul - Portland/Seattle route. Two trains arrive and depart daily, one eastbound and one westbound.

4.2.3.12.4 Bus

Metro Area Transit, or MAT, Fargo-Moorhead's public bus system, operates 6 days per week on 18 different routes though Fargo, Moorhead and West Fargo; accumulating over 1 million miles each year. Bus travel begins at 6 am (Monday- Friday) and ends as late as 10:15 pm (Monday-Friday). Saturday operations are from 7 am until 7 pm. Services provided by MAT include: Para-transit, wheelchair accessibility, bike racks, fare-free rides for college students and park-and-ride.

Fargo-Moorhead has a Greyhound bus station in the central station of the MAT, located in downtown Fargo. Fargo-Moorhead's Greyhound routes run east to Minneapolis/St. Paul, MN;

west through Bismarck, ND to Billings, MT; south to Sioux Falls, SD; and north to Grand Forks, ND.

5.0 ENVIRONMENTAL CONSEQUENCES*

5.1 ENVIRONMENTAL EVALUATION METHODOLOGY

An environmental analysis was conducted for the selected plan and its alternatives, and a discussion of those impacts is presented below. In accordance with the Clean Water Act, a Section 404(b)(1) evaluation has been prepared and is incorporated by reference. It can be found in Attachment 1. The project is in compliance with the Section 404(b)(1) Guidelines. The no action alternative assumes no federal action but does assume full implementation of emergency protection actions so that some level of flood risk management will continue for the community.

This chapter describes the predicted impacts of the alternatives, including the consequences of the no action alternative, on the relevant environmental resources described in Chapter 4. It evaluates direct, indirect, and cumulative effects, and quantifies these effects whenever possible. Measures and commitments intended to mitigate adverse environmental impacts are described in Attachment 6.

5.2 EFFECTS ON SIGNIFICANT RESOURCES

The analyses recognize that there are links between resources. For example, if an alternative affects streamflows, it may also in turn affect aquatic communities and riparian areas. Changes in these resources could, over time, impact wildlife and cultural resources. Throughout these impact assessments, linkages are discussed where appropriate and are quantified when possible. The significant resources were identified during the scoping process and outlined in the Scoping Document in Appendix F. The effects on these resources are identified in this chapter. Not all resources are highlighted from the scoping document since they will not be affected by the evaluated alternatives.

The "diversion channel alternatives" includes a Minnesota diversion channel sized to carry 35,000 cfs of flow (FCP), a North Dakota diversion channel sized to carry a 35,000 cfs flow (ND35K), and a North Dakota diversion channel sized to carry approximately 20,000 cfs of flow (LPP). The FCP and ND35K alternatives would be operated in a manner that would cause downstream impacts; while the LPP will have features incorporated to minimize downstream impacts, but will have impacts upstream. The features for the three alternatives are described in detail in Chapter 3. Impacts for the no action alternative are only discussed for the resources where there is expected to be an impact; these include water quality, wetlands and floodplain.

Natural Resources

- Geomorphology
- Air Quality
- Water Quality
- Water Quantity
- Wetlands
- Shallow Groundwater
  - Aquifers
- Fisheries and Aquatic Habitat

  - Fish Passage
- Upland Habitat/Riparian Habitat
- Terrestrial Wildlife
- Endangered Species
- Prime and Unique Farmland
- Hazardous, Toxic and Radioactive Waste (HTRW)
- Climate

Cultural Resources

Socioeconomic Resources
- Social Effects
- Economic Issues
- Environmental Justice

5.2.1 Natural Resources

5.2.1.1 Geomorphology

With the diversion channel alternatives, a proportion of water from the Red River, and select tributaries with the North Dakota diversion alignment, will be diverted around the study area. The proportion and timing of flow diverted will depend on many factors, including the alternative, flood magnitude, and location within the study area relative to project features. Project features will effectively reduce the flood flows into the protected area for events greater than the 50-percent chance event to the 10-percent chance event. This could potentially impact downstream sediment transport and geomorphology of the streams in the study area. For the FCP, this could influence approximately 42 miles or more of Red River habitat. For the LPP and ND35K, this could influence approximately 60 miles of Red River habitat downstream of the control structure, as well as 12 to 13 miles of the Wild Rice River, 43 miles of the Sheyenne River and 3.5 miles of the Maple River downstream of their respective structures. The project also could influence approximately 1.8 miles of Wolverton Creek through operation of a gate located at the tie-back levee under the LPP. In addition to downstream effects, the LPP includes the upstream staging of water on the Red and Wild Rice rivers, as well as Wolverton Creek, which could also affect upstream geomorphic conditions. Finally, construction of most project features will be done outside of existing channels, with rivers permanently re-routed through these features. This could change channel length and slopes and cause channel instability.

5.2.1.1.1 Effect of altered hydraulics and sediment transport on downstream geomorphology

With all of the diversion channel alternatives the flow regime in the Red River within the study area could change the capacity of the river to transport sediment. The LPP and ND35K alternatives also could affect the Maple, Sheyenne and Wild Rice rivers, as well as Wolverton Creek, downstream of their respective structures. However, because all of the affected rivers appear dominated by the transport of fine suspended material (see Exhibit I of Appendix F of Attachment 5 (IF5)), the diversion of a fraction of the river flow is expected to divert a proportional fraction of the total sediment load transported as suspended sediment. This suspended sediment, being fine-grained with very slow settling velocities, can be expected to move through these diversion systems and return to the Red River downstream of Fargo and Moorhead. The changes to river flows within the protected area are not expected to be sufficient for the remaining fraction of the suspended sediment to settle. Therefore, the total sediment budget of the system will be essentially unchanged for all diversion channel alternatives.

The Horace/West Fargo Diversion of the Sheyenne River provides an example of the potential maximum impacts that can be expected from the diversion channel alternatives. As discussed in IF5, the Sheyenne River system has coarser bed material and more coarse suspended sediment than the other affected rivers, meaning that the impacts of diversion on sediment transport would be expected to be the most significant. However, even the somewhat coarser suspended sediment in the Sheyenne River is passed to the diversion channel in proportion to the flow, validating the description of expected future conditions proposed above. Although the bed material of the Sheyenne River (and most of the other rivers in this study) appears to consist of fine or medium sand, this more coarse material is not transported in significant quantities through the system. What little bedload sediment is in the Sheyenne River appears to move primarily past the diversion structure and into the protected area. The presence of the diversion channel and diversion control structures does not appear to have altered the geomorphic behavior of the Sheyenne River within the study area. Recent modeling (West 2001) has shown that monitored locations on the lower Sheyenne River experienced only slight adjustments to channel shape over more than 50 years, including periods after the construction of the two Sheyenne River diversion projects, which have been in place for nearly 20 years. The slight widening of the river in these areas was expected based on the hydrology of the larger Sheyenne River, and was not interpreted as a response to local changes in the flow regime caused by the diversion.

With all of the diversion channel alternatives, it is expected that the diversion of additional flood water will have a similarly small impact on the downstream geomorphology, including channel size and stability, of the rivers under concern. This initial conclusion will be examined more thoroughly during the ongoing geomorphic study of the area rivers being performed for this study. The potential project impacts to the downstream geomorphology of the Red River and its tributaries from the discussed changes in sediment transport are expected to be negligible (see IF5). The Red River is a stable riverine system, neither aggrading nor degrading, with sediment transport primarily in suspension. These characteristics are not expected to change significantly following construction of any of the diversion channel alternatives.

5.2.1.1.2 Effect of altered channel length on channel stability

Construction of the Red River control structure could alter stream length adjacent to the feature under any of the diversion channel alternatives. Under the LPP and ND35K, additional structures could similarly impact channel slope on the Wild Rice, Sheyenne and Maple rivers. Changes in channel length for Wolverton Creek would be fairly small and localized, relative to these other tributaries. Changes in stream length would cause a proportional increase in local slope and could trigger channel instability.

Existing slopes in the area of flow control structures include:

- Red River: 0.006%
- Wild Rice River: 0.004%

- Sheyenne River: 0.017%
- Maple River: 0.024%

Based on aerial measurements for the LPP and ND35K, realignment of the channel on these rivers would result in the following approximate changes in stream length. Conditions around the Red River control structure under the FCP would be similar.

- Red River: new channel 78% of existing channel
- Wild Rice River: new channel 56% of existing channel
- Sheyenne River: new channel 88% of existing channel
- Maple River: new channel 77% of existing channel

Although all new channels would result in a decrease in channel length, these changes will not necessarily cause increased velocity or trigger instability in the realigned channel. The realigned channel will not necessarily have the same cross-sectional area as the abandoned channel. Careful design would be able to maintain approximately the same channel velocities during lower-flow conditions by altering the cross-sectional area of the realigned channel (i.e. provide a slightly wider channel to compensate for the slightly higher slope). Given the very low slopes typical of these rivers, the locally increased slopes will likely not be out of the range of slopes observed in short reaches of the existing rivers. Under high-flow conditions, flow through the realigned channels will typically be controlled by downstream tailwaters and the velocities will not be sensitive to the small local changes in channel slope proposed here. With careful design and planning under any of the diversion channel alternatives, the shortening of river channels would not cause substantial changes to channel stability or geomorphic condition at the placement of structures.

5.2.1.1.3 Effect of upstream staging on upstream geomorphology

The LPP includes upstream staging of water on the Red and Wild Rice rivers, as well as Wolverton Creek, which could affect upstream geomorphic conditions. The degree of upstream staging is discussed in Section 3.7 and Section 5.2.1.4. This condition is not a part of any other diversion channel alternative.

Given the flat slope of the Red River and its valley floor, upstream staging can influence water elevations for several miles upstream. In addition to water elevation, staging can influence water distribution, flow patterns, velocity, and potentially sedimentation and sediment transport. It could also influence bank stability and the potential for bank failure.

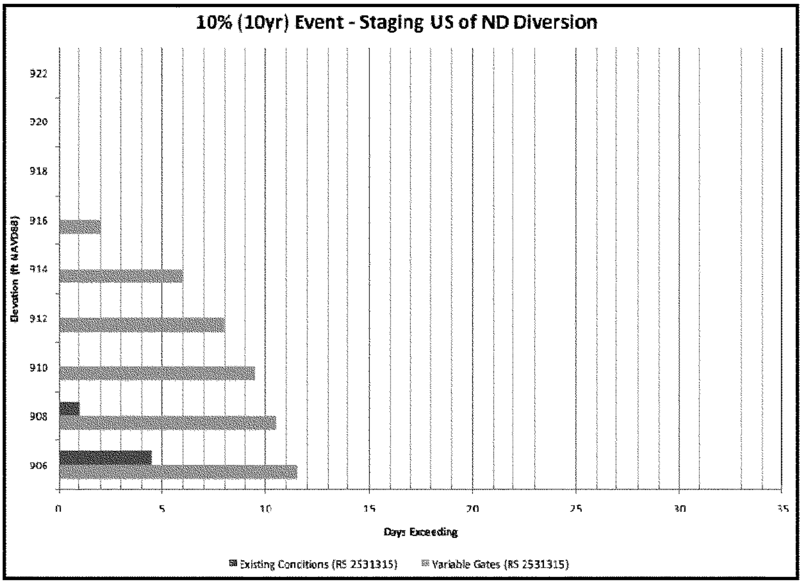
Under existing conditions, bank failures are extremely common throughout the Red River valley, especially on the outside bends of most rivers. Many bank failures have already been identified within the Fargo/Moorhead area, including upstream areas where staging could take place under the LPP. Bank failures often are triggered or exacerbated by receding water levels, with failures most influenced under the following conditions: 1) drought conditions, where water elevations are reduced to levels below those that have occurred for many previous weeks, months or even years; and 2) receding water levels associated with the diminishing limb of a flood hydrograph.

The frequency of project operations would be tied to a flow threshold (e.g., 9,600 cfs in the Red River at Fargo) that is equal to or larger than the bankfull discharge. Thus, the LPP will not be increasing the frequency that upstream elevations rise above bankfull. Similarly, upstream staging under the LPP will not substantially change flow velocities near the Red River channel banks during conditions when water is staged.

Under the LPP, increased duration of water elevations might contribute towards a slight increase in bank instability as a result of increased soil saturation and potentially reduced soil strength in bankline areas. As water elevations drop toward the end of project operations during a flood, bank failures could be triggered or exacerbated. This risk would be greatest at the outer face of the lower bank.

Under the LPP, modeled water elevations immediately upstream of the Red River control structure for a 10-percent chance event would exceed 906 ft (an elevation a few feet above bankfull) approximately seven days longer than existing conditions (Figure 1). While the duration of this and other flood events could vary, the incremental differences in durations (With versus Without Project) generally under consideration here would not be expected to substantially change soil strength conditions. Under the LPP, changes in stability of the outer face of the lower bank would likely be extremely small. In addition, the stability of a larger portion of the lower bank, as well as the upper bank, would not likely be substantially affected by a small increase in duration of bankfull conditions. Also, the LPP should not lead to a meaningful change or increase in key de-stabilizing forces around bankline areas. These include flow velocities, or boundary shear stress applied on the channel banks. Relative to the Future without project condition, the LPP would not be anticipated to result in a substantial increase in bank failure conditions, or substantially exacerbate existing slides, upstream of the project.

Figure 52 Comparison of Increased Water Surface Elevations, between with-project and existing conditions, Upstream of the Red River Control Structure for the simulated 10-percent chance event.



While some sedimentation may occur across inundated upstream areas, it is not expected that a substantial amount of material will settle from the water, relative to the total amount being transported by the river during flooding. The amount of settlement would not be expected to substantially reduce the amount of sediment transported during floods, and thus trigger additional geomorphic concerns upstream or downstream of the control structures. Also, any settlement that would occur would cause negligible increases in floodplain elevations behind the control structures. Based on sediment transport observations from the 2010 flood, even if all river sediment settled during such a flood during project operation, the average level of elevation increase across the inundated area would be less than 0.02 inches under those conditions. This would not significantly influence floodwater storage, or reduce the ability to stage water upstream. Uniform distribution of sediment deposition over the entire upstream floodplain would not be expected during floods, but deviations from average sediment deposition rates would not be substantial. If the conservative estimates presented here would be off by one to two orders of magnitude in some localized areas, the sedimentation rates in such areas would be 2-3 inches, which is well within the expected range of sedimentation driven by natural processes during large flood events in a complex riverine system where sediment transport is dominated by very fine material (silts and clays) mobilized in suspension.

5.2.1.2 Air Quality
The Fargo-Moorhead area is considered a National Ambient Air Quality Standards (NAAQS) Attainment Area for all air quality parameters (USEPA 2009). The air quality effects of the diversion channel alternatives would be the same or similar. Heavy equipment would produce small amounts of hydrocarbons in exhaust emissions compared to total hydrocarbon emission in the area. The construction contractor would be required to maintain the vehicles on the sites in good working order to minimize exhaust emissions. Fugitive dust could also result from construction activities so the contractor would be required to conduct dust suppression activities. Adverse impacts to air quality resulting from the activities would be minor and short term in nature regardless of the alternative that is implemented.

5.2.1.3 Water Quality
5.2.1.3.1 No Action Alternative
There are many initiatives and programs in place in the study area that have and will continue to improve water quality. The Red River Basin Commission has been working with the local soil and water conservation districts, watershed districts and Pheasants Forever on the Red River Basin Buffer initiative. The goals of this initiative are to demonstrate a process for restoring strategically targeted riparian buffers within a small watershed so the process can be duplicated throughout the Red River Basin. This initiative will also demonstrate the water quality benefits of these restorations. Measurable goals include establishing buffers, restoring prescribed wetlands within the watersheds, reducing sediment concentrations/loads at stream sites, reducing total phosphorus concentrations/loads at stream sites, and educating the public about benefits of buffers to promote their implementation. Water quality is expected to improve under the no action alternative.

5.2.1.3.2 All diversion channel alternatives
All of the diversion channel alternatives would likely have temporary minor adverse impacts on surface water quality. The removal of the river substrate and the placement of rock would result in moderate increases in suspended solids in the river water during the construction period. Once the construction has been completed, water quality would return to pre-project conditions. Erosion from storm water runoff from the terrestrial construction areas also could have the potential to negatively impact surface water quality during construction and until the area has developed a protective ground cover. In order to minimize any erosion and sedimentation that could occur, a Storm Water Pollution Prevention Plan (SWPPP) would be prepared for the site, and the measures indicated in the plan would be implemented for any alternative that is constructed. The SWPPP would contain specific construction measures (e.g., silt curtains, silt fences, drainage swales, hay bales, etc.) to reduce or eliminate runoff impacts during construction activities and reduce the potential for soil erosion after construction. Best management practices (BMPs) as provided by the Environmental Protection Agency (EPA), Storm Water Pollution Prevention Plan Guidance from the North Dakota Department of Health NDPDES program, or in the Minnesota Pollution Control Agency's "Protecting Water Quality in Urban Areas: A Manual" would be used. The construction contractor would also be required to implement protective measures to prevent spillage of chemicals, fuels, oils, greases, bituminous materials, waste washings, herbicides, insecticides, or any other materials associated with construction activities, and keep these materials from entering drainages. With implementation

of measures identified in the SWPPP and the incorporation of BMPs to reduce spillage, all of the diversion channel alternatives would be anticipated to have only temporary, minor adverse impacts on surface waters.

5.2.1.4 Water Quantity

All of the diversion channel alternatives will change the timing and flows of water, significantly reducing the quantity of water flowing through the communities of Fargo and Moorhead. As a result of the modifications to the timing of the flows, downstream and/or upstream impacts are anticipated. These impacts are identified in Table 41-Table 44.

These tables show the increase in inches of water depths downstream at nineteen locations and upstream at three locations with the project in place versus existing conditions with no emergency measures in place.

5.2.1.4.1 FCP

Analysis for the FCP alternative for downstream impacts compares stages for existing conditions versus 10-, 2-, 1-, and 0.2-percent chance events. Table 41-Table 44 and Figure 53 - Figure 56 indicate the difference in water quantities for these events compared to existing conditions with no emergency protection in place.

The affected area for the FCP was based on the diversion outlet entering the Red River at RM427. The analysis extends downstream 272 river miles to Emerson at RM155. This defines the area analyzed for the FCP. The number of acres currently affected, with no emergency protection in place, for the 10-percent chance event within the area analyzed is 224,205 acres. The area affected during a 10-percent chance event with the FCP in place would be 231,553 acres, for an increase of 7,348 acres. The depth of increase will vary throughout the area with increases from 0.1 inch to 2.9 inches expected. The number of acres currently affected for the 2-percent chance event is 347,214 acres. The area affected during a 2-percent chance event with the FCP in place would be 357,200 acres, for an increase of 9,986 acres. The depth of increase will vary throughout the area with increases from 0.1 inch to 9.7 inches. The number of acres currently affected for the 1-percent chance event is 390,942 acres. The area affected during a 1-percent chance event with the FCP in place would be 409,163 acres, for an increase of 18,221 acres. The depth of increase will vary throughout the area with increases from 0.7 inch to 12.5 inches. The number of acres currently affected for the 0.2-percent chance event is 522,229 acres. The area affected during a 0.2-percent chance event with the FCP in place would be 531,975 acres, for an increase of 9,566 acres. The depth of increase will vary throughout the area with increases from 0.8 inch to 5.6 inches (Table 41- Table 44, Figure 53 –Figure 56). The figures only show impacts to Drayton, which is 50 miles upstream of Emerson.

Increases in the level and duration of downstream flooding would have no appreciable effects on natural resources, but may result in significant adverse effects on social resources.

Table 41 – Downstream and upstream water quantity, LPP, FCP, and ND35K – 10%

10% Chance (10-Year) Event			
Location	Stage Increase (Inches)		
	LPP	**FCP**	**ND35K**
Downstream Locations			
Emerson Gage	–	0.1	–
Pembina Gage	–	0.1	–
Drayton Gage	0.1	0.1	–
ND SH#17/MN SH317	0.2	0.1	–
Co. Hwy 15	0.1	0.1	–
Oslo Gage	0.5	0.1	–
DS Grand Forks Levees	1.0	0.2	–
Grand Forks Gage	1.3	0.2	–
LPP Maximum DS Impact Location	1.4	–	–
32nd Ave, Grand Forks	1.3	0.4	–
Thompson Gage	0.5	1.2	12.2
Hwy 25/Co.Rd 221	0.5	1.4	13.3
ND35K Maximum Impact Location	–	–	13.9
DS Sandhill River/Climax	0.4	1.6	13.6
Nielsville	0.4	1.6	12.6
DS Marsh River	0.5	1.6	11.9
US Goose River/Shelly	0.4	1.8	12.0
Halstad Gage	-1.4	1.8	7.6
Hendrum	-3.0	1.9	8.0
Perley	-6.5	2.4	11.4
Georgetown	-5.2	1.8	10.6
FCP (MN35K) Maximum Impact Location	–	2.9	–
Upstream Locations			
US FCP Diversion	–	1.6	–
US ND Wild Rice River	-61.8	-1.8	-65.2
US LPP Diversion	98.8	–	-0.6
Hickson Gage	79.0	0.5	0.6
Abercrombie	1.3	0.0	–

Table 42 – Downstream and upstream water quantity, LPP, FCP, and ND35K – 2%

2% Chance (50-Year) Event			
Location	Stage Increase (Inches)		
	LPP	**FCP**	**ND35K**
Downstream Locations			
Emerson Gage	–	0.7	–
Pembina Gage	–	1.3	–
Drayton Gage	1.0	1.2	–
ND SH#17/MN SH317	0.8	1.2	–
Co. Hwy 15	0.6	1.1	–
Oslo Gage	0.5	0.4	–
DS Grand Forks Levees	1.3	0.8	–
Grand Forks Gage	2.2	1.2	–
32nd Ave, Grand Forks	3.4	2.8	–
LPP Maximum DS Impact Location	4.6	–	–
Thompson Gage	2.9	6.7	20.9
Hwy 25/Co.Rd 221	2.5	8.8	26.9
ND35K Maximum Impact Location	–	–	29.4
DS Sandhill River/Climax	2.5	9.2	29.3
Nielsville	2.2	9.6	25.3
FCP (MN35K) Maximum Impact Location	–	9.7	–
DS Marsh River	1.9	8.5	22.2
US Goose River/Shelly	1.4	8.0	17.3
Halstad Gage	0.0	4.8	10.3
Hendrum	-1.4	4.9	15.1
Perley	-3.8	4.0	9.4
Georgetown	-2.8	3.6	8.0
Upstream Locations			
US FCP Diversion	–	-1.8	–
US ND Wild Rice River	-112.9	0.6	-112.2
US LPP Diversion	85.2	–	0.0
Hickson Gage	55.0	0.4	0.2
Abercrombie	1.7	0.1	–

Table 43 - Downstream and upstream water quantity, LPP, FCP and ND35K – 1%

1% Chance (100-Year) Event			
Location	Stage Increase (Inches)		
	LPP	**FCP**	**ND35K**
Downstream Locations			
Emerson Gage	–	0.7	–
Pembina Gage	–	2.0	–
Drayton Gage	1.0	1.7	–
ND SH#17/MN SH317	0.8	1.6	–
Co. Hwy 15	0.6	1.8	–
Oslo Gage	0.7	1.1	–
DS Grand Forks Levees	1.8	2.5	–
Grand Forks Gage	2.9	4.1	–
LPP Maximum DS Impact Location	3.5	–	–
32nd Ave, Grand Forks	3.4	5.8	–
Thompson Gage	0.5	7.0	15.8
Hwy 25/Co.Rd 221	-0.2	10.7	23.6
ND35K Maximum Impact Location	–	–	25.4
DS Sandhill River/Climax	-0.5	11.8	25.3
FCP (MN35K) Maximum Impact Location	–	12.5	–
Nielsville	-0.5	12.4	22.8
DS Marsh River	-0.4	10.7	19.4
US Goose River/Shelly	-0.5	9.2	15.1
Halstad Gage	-0.7	6.2	10.4
Hendrum	-0.7	6.6	11.3
Perley	-3.4	6.6	7.6
Georgetown	-3.0	5.8	8.4
Upstream Locations			
US FCP Diversion	–	6.8	–
US ND Wild Rice River	-107.9	5.3	-105.1
US LPP Diversion	98.8	–	0.2
Hickson Gage	64.6	-0.1	0.1
Abercrombie	1.3	0.0	–

Table 44 - Downstream and upstream water quantity, LPP, FCP and ND35K – 0.2%

0.2% Chance (500-Year) Event			
Location	Stage Increase (Inches)		
	LPP	FCP	ND35K
Downstream Locations			
Emerson Gage	–	1.0	–
Pembina Gage	–	2.2	–
Drayton Gage	1.3	1.0	–
ND SH#17/MN SH317	0.8	1.0	–
Co. Hwy 15	1.1	1.2	–
Oslo Gage	0.6	0.8	–
DS Grand Forks Levees	1.4	1.9	–
Grand Forks Gage	2.6	4.6	–
LPP Maximum DS Impact Location	3.2	–	–
FCP (MN35K) Maximum Impact Location	–	5.6	–
32nd Ave, Grand Forks	2.8	5.6	–
Thompson Gage	-0.6	2.4	7.2
Hwy 25/Co.Rd 221	-1.4	3.4	6.6
DS Sandhill River/Climax	-1.8	3.8	7.9
ND35K Maximum Impact Location	–	–	8.4
Nielsville	-1.9	4.4	7.7
DS Marsh River	-1.7	4.1	7.3
US Goose River/Shelly	-1.6	3.7	6.5
Halstad Gage	-2.6	1.7	3.7
Hendrum	-3.6	0.8	1.4
Perley	-4.3	-0.4	0.6
Georgetown	-4.0	-0.5	0.2
Upstream Locations			
US FCP Diversion	–	-2.3	–
US ND Wild Rice River	-15.7	2.9	-9.0
US LPP Diversion	78.0	–	1.7
Hickson Gage	34.2	-0.1	-0.4
Abercrombie	0.1	0.0	–

Figure 53 - 10-percent chance event (10-year) downstream extent to Drayton—existing vs. FCP

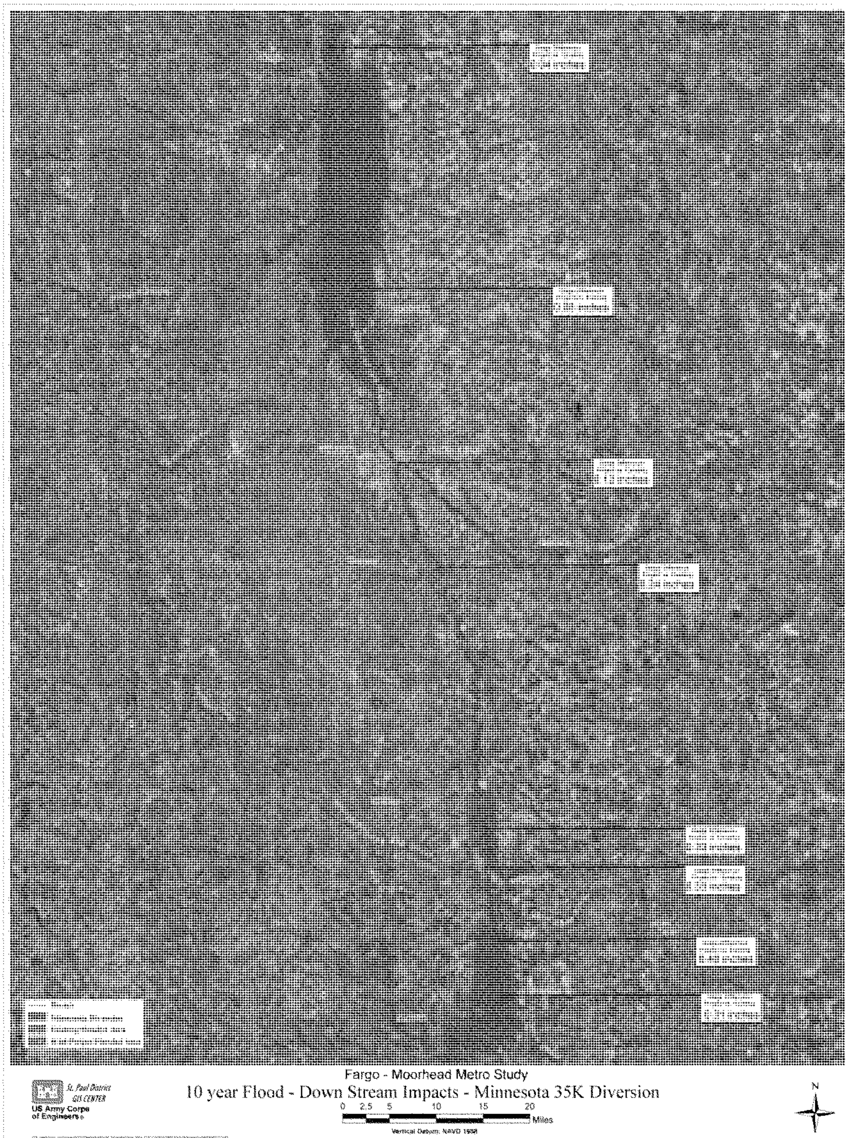


Figure 54 - 2 percent chance event (50-year) downstream extent to Drayton—existing vs. FCP

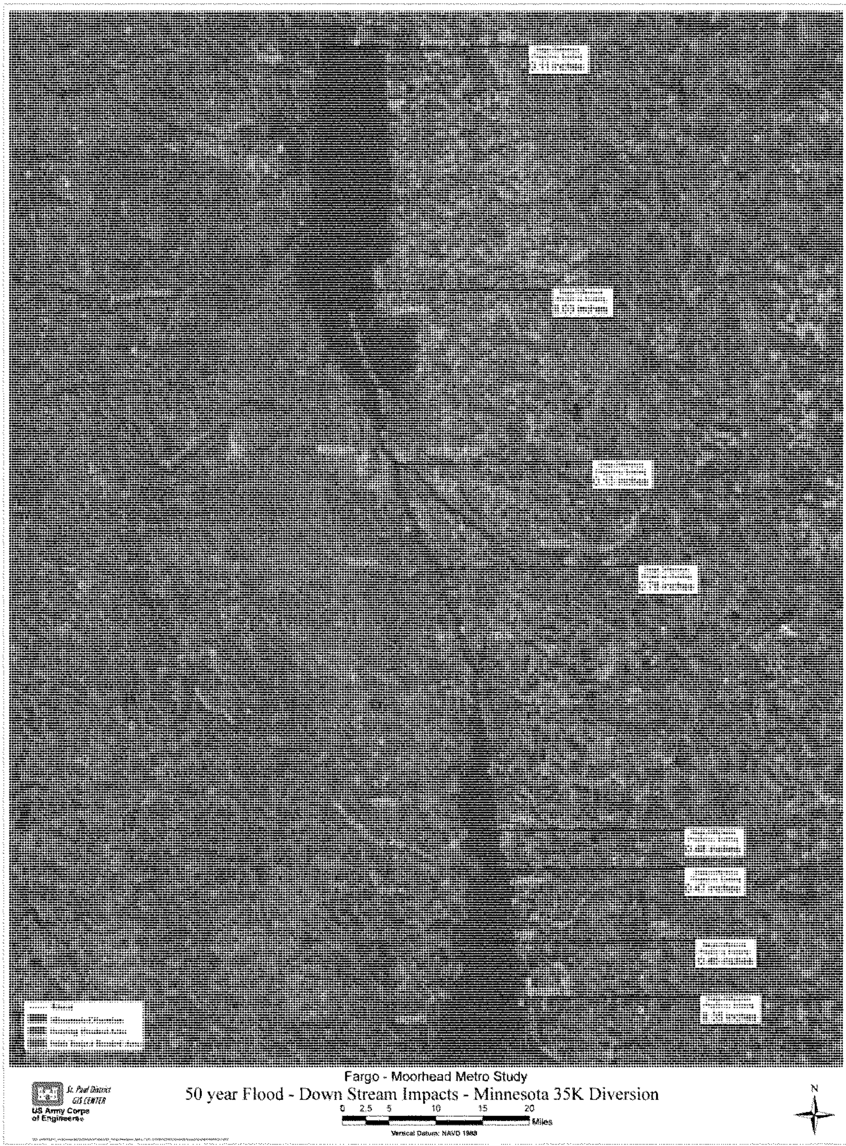


Figure 55 – 1-percent chance event (100-year) downstream extent to Drayton—existing vs. FCP

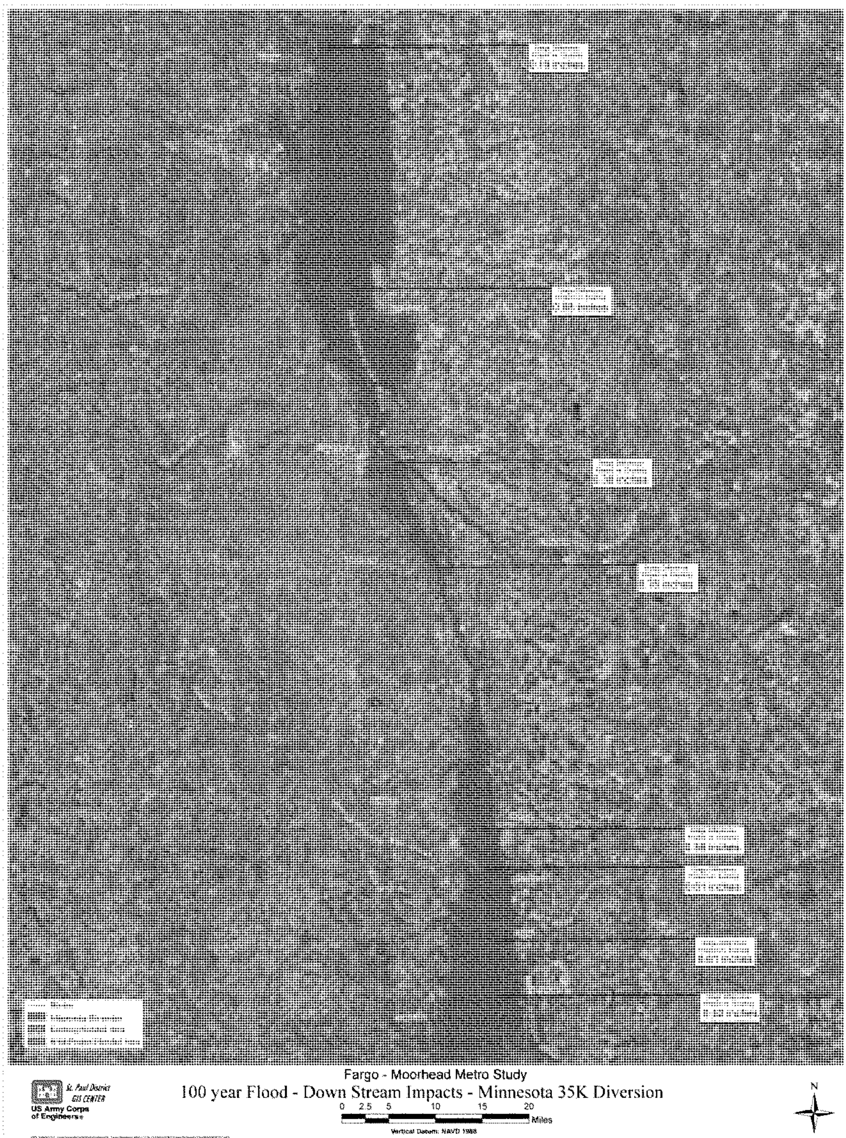
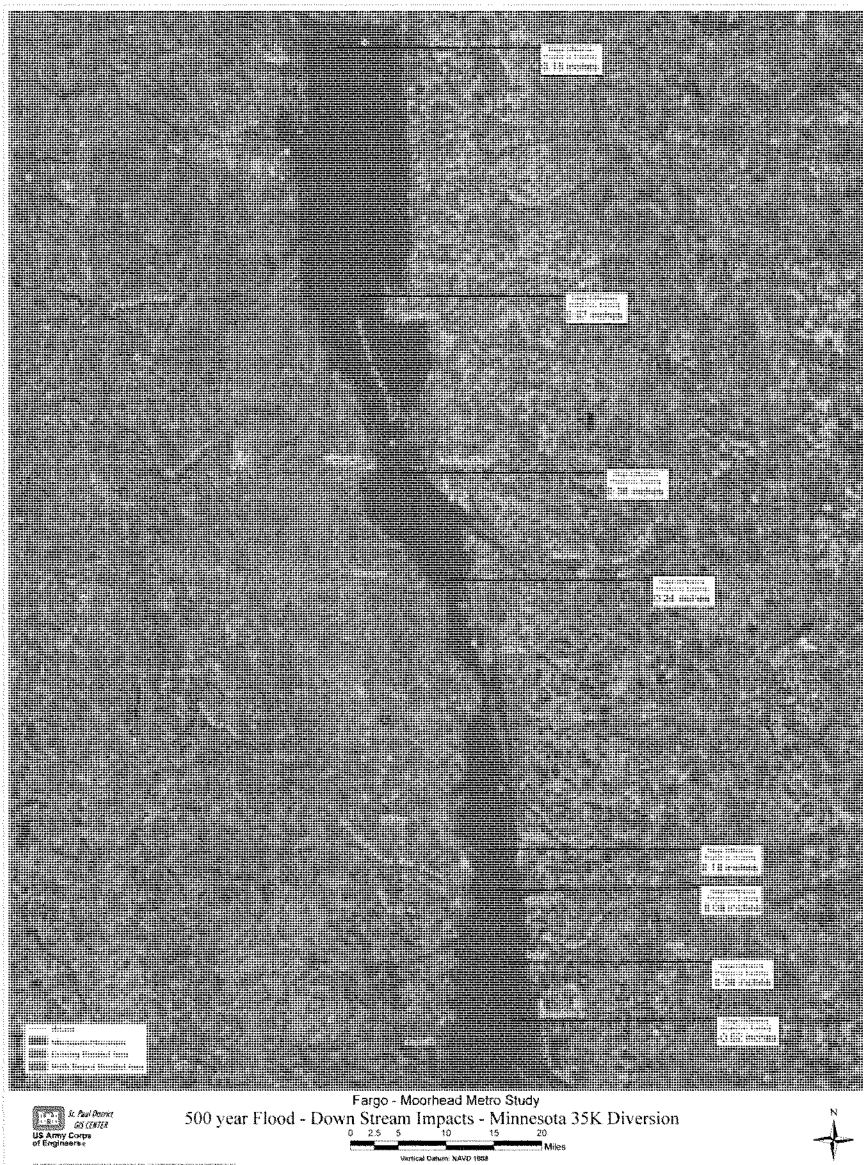


Figure 56 - 0.2-percent chance event (500-year) downstream extent to Drayton—existing vs. FCP



5.2.1.4.2 ND35K

The ND35K alternative was analyzed for downstream impacts. Table 41 - Table 44 and Figure 57 - Figure 64 indicate the difference in water quantity for the 10, 2, 1, and 0.2-percent chance flood events between the conditions with the ND35K plan in place and the existing conditions with no emergency protection in place.

The affected area for the ND35K was based on the diversion outlet entering the Red River at RM 418.5. The analysis extends downstream 102 river miles to Thompson, ND at RM 316. This defines the area analyzed for the ND35K plan. The number of acres currently affected, with no emergency protection in place, for the 10-percent chance event within the area analyzed is 45,676 acres. The area affected during a 10-percent chance event with the ND35K plan in place would be 56,821 acres, for an increase of 11,145 acres. The depth of increase will vary throughout the area with increases from 0.6 inch to 13.9 inches. The number of acres currently impacted for the 2-percent chance event is 112,936 acres. The area affected during a 2-percent chance event with the ND35K plan in place would be 126,705 acres, for an increase of 13,769 acres. The depth of increase will vary throughout the area with increases from 0.2 inch to 29.4 inches. The number of acres currently affected for the 1-percent chance event is 129,424 acres. The area affected during a 1-percent chance event with the ND35K plan in place would be 142,299 acres, for an increase of 12,875 acres. The depth of increase will vary throughout the area with increases from 0.1 inch to 25.4 inches. The number of acres currently affected for the 0.2-percent chance event is 183,296 acres. The area affected during a 0.2-percent chance event with the ND35K plan in place would be 192,602 acres, for an increase of 9,306 acres. The depth of increase will vary throughout the area with increases from 0.2 inch to 8.4 inches. The ND35K plan was not modeled any further than Thompson, ND because the impacts were far greater than those for the FCP. It was assumed that the impacts would continue to be greater than the FCP all the way to Emerson.

Increases in the level and duration of downstream flooding would have no appreciable effects on natural resources, but may result in significant adverse effects on social resources.

Along the North Dakota tributaries outside of the diversion channel minor changes to existing conditions may occur. The inlets to the diversion channel will be designed to maintain the existing 1-percent floodplain. The design of the inlets could result in minor drainage benefits for frequent events, such as rainfall events. During operation of the diversion channel, flows will generally stay below existing ground up to the 1-percent chance event; this will allow the diversion to receive local drainage. Once the existing ground level is exceeded, local drainage into the diversion could be limited or stop in some cases, however it is not anticipated that flood levels outside of the diversion would exceed existing conditions.

Figure 57 – 10-percent chance event (10-year) downstream to Halstad—existing vs. ND35K

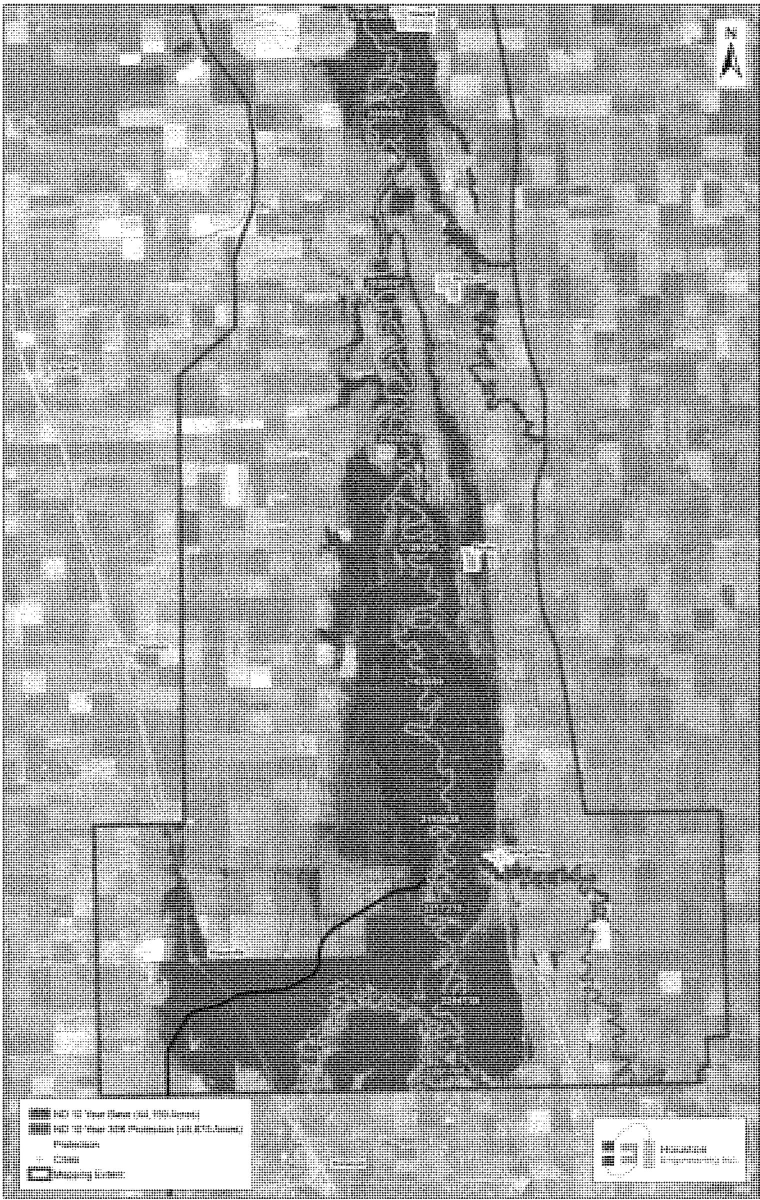


Figure 58 – 10-percent chance event (10-year) from Halstad to Thompson—existing vs. ND35K

Figure 59 – 2-percent chance event (50-year) downstream to Halstad-existing vs. ND35K

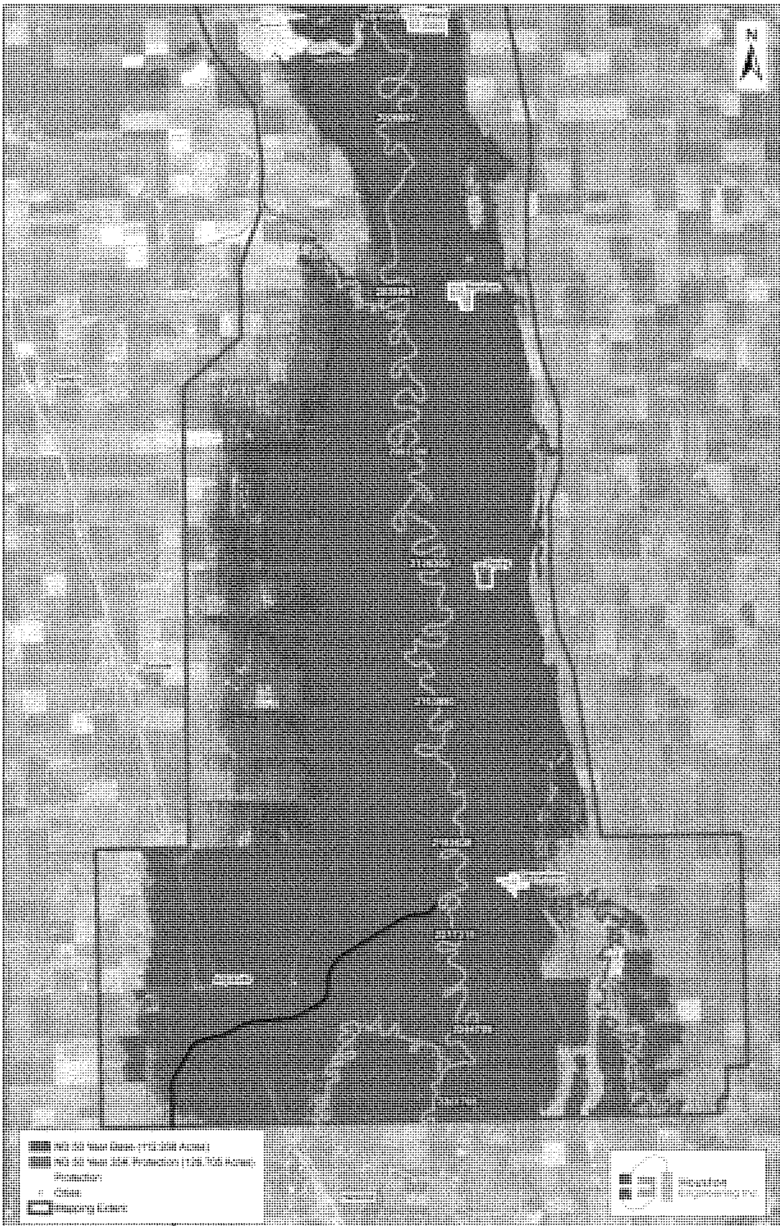


Figure 60 – 2-percent chance event (50-year) from Halstad to Thompson—existing vs. ND35K

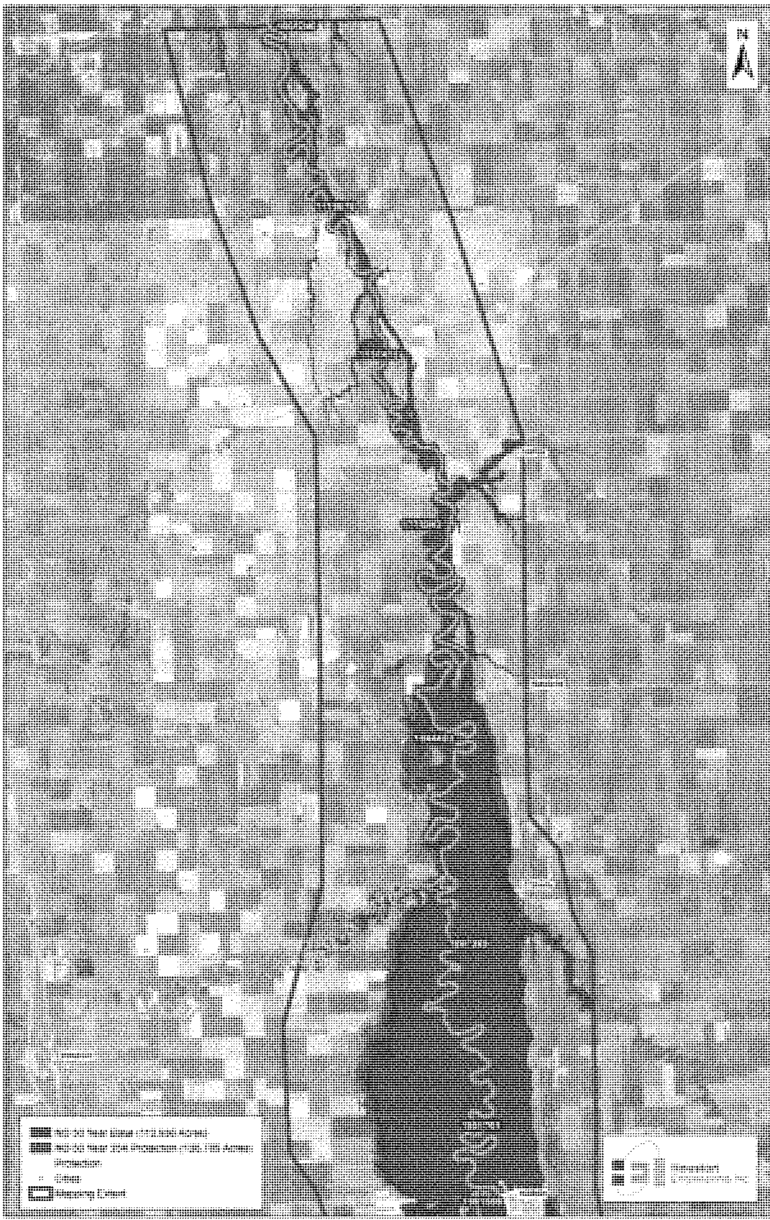


Figure 61 – 1-percent chance event (100-year) downstream to Halstad—existing vs. ND35K

Figure 62 – 1-percent chance event (100-year) from Halstad to Thompson—existing vs. ND35K

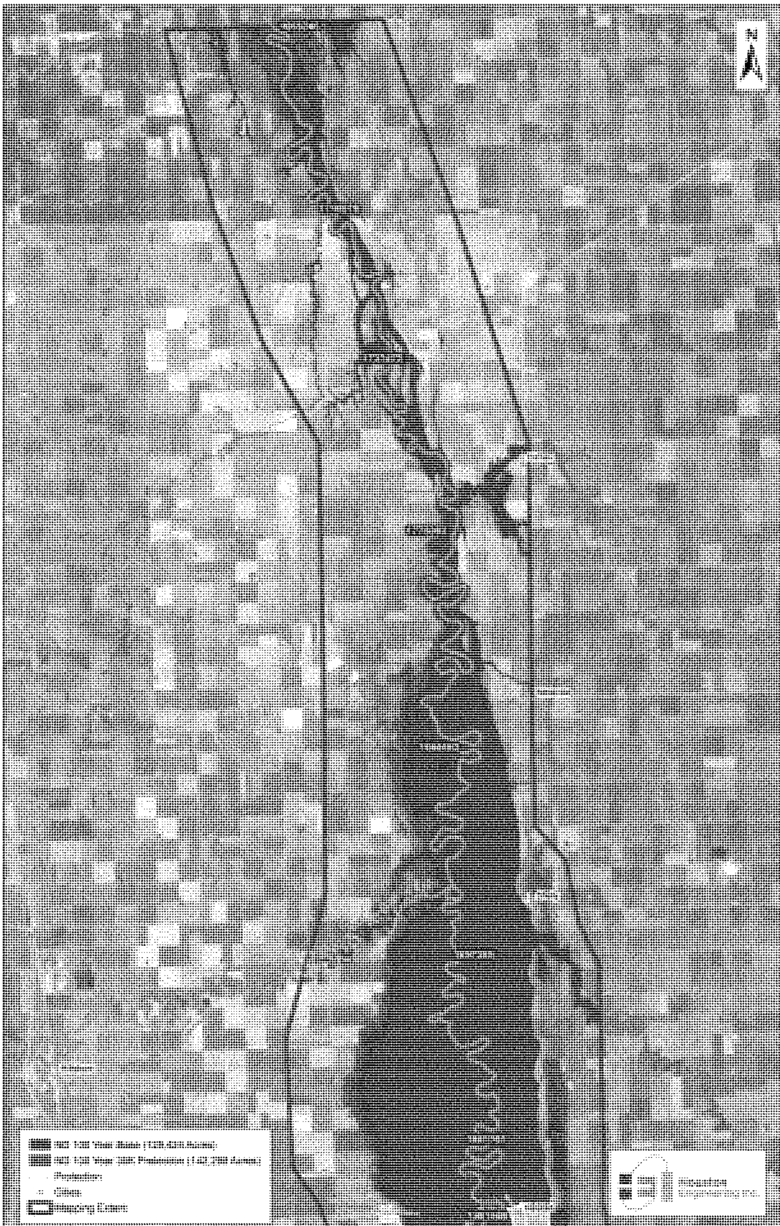
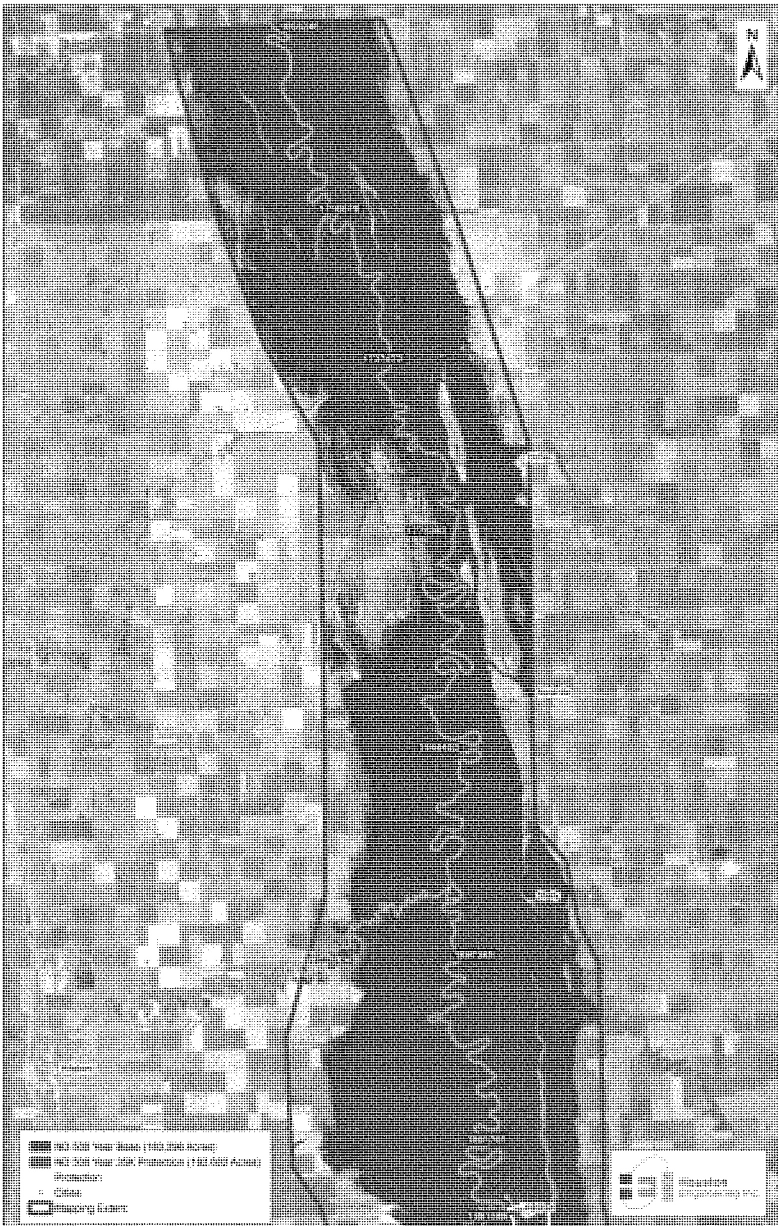


Figure 63 - 0.2-percent chance event (500-year) downstream to Halstad—existing vs. ND35K

Figure 64 - 0.2 percent chance event (500-year) from Halstad to Thompson—existing vs. ND35K



5.2.1.4.3 LPP

The LPP alternative was analyzed for downstream and upstream impacts. Table 41 - Table 44 and Figure 65 - Figure 74 indicate the difference in water quantity for the 10, 2, 1, and 0.2-percent chance flood events between the conditions with the LPP in place and the existing conditions with no emergency protection in place.

The downstream affected area for the LPP was based on the diversion outlet entering the Red River at RM 418.5. The analysis extends downstream 210 river miles to Drayton, ND at RM 208. This defines the extent of the downstream area analyzed for the LPP. The number of acres currently affected downstream, with no emergency protection in place, for the 10-percent chance event within the area analyzed is 224,166 acres. The area affected during a 10-percent chance event with the LPP in place would be 221,176 acres, for a decrease of 2,990 acres. The number of acres currently affected upstream for the 10-percent chance event with no emergency protection in place is 7,858 acres, while the area affected for a 10-percent chance event with the LPP in place is 20,841 acres. This would be an increase of 12,983 acres at varying levels of depth. The depth of increase will vary throughout the area with increases from 0.1 inch to 98.8 inches expected. The number of acres currently affected downstream for the 2-percent chance event is 347,158 acres. The area affected during a 2-percent chance event with the LPP in place would be 346,696 acres, for a decrease of 462 acres. The number of acres currently affected upstream for the 2-percent chance event is 20,363 acres, while the area affected for a 2-percent chance event with the LPP in place is 38,000 acres. This would be an increase of 17,637 acres at varying levels of depth. The depth of increase will vary throughout the area with increases from 0.5 inch to 85.2 inches expected. The number of acres currently affected downstream for the 1-percent chance event is 390,866 acres. The area affected during a 1-percent chance event with the LPP in place would be 390,557 acres, for a decrease of 309 acres. The number of acres currently affected upstream for the 1-percent chance event is 31,546 acres, while the area affected for a 1-percent chance event with the LPP in place is 54,721 acres. This would be an increase of 23,175 acres at varying levels of depth. The depth of increase will vary throughout the area with increases from 0.5 inch to 98.8 inches expected. The number of acres currently affected downstream for the 0.2-percent chance event is 521,944 acres. The area affected during a 0.2-percent chance event with the LPP in place would be 521,738 acres, for a decrease of 206 acres. The number of acres currently affected upstream for the 0.2-percent chance event is 66,566 acres, while the area affected for a 0.2-percent chance event with the LPP in place is 78,876 acres. This would be an increase of 12,310 acres at varying levels of depth. The depth of increase will vary throughout the area with increases from 0.1 inch to 78.0 inches expected. (Table 41 and Figure 65 - Figure 74.)

Along the North Dakota tributaries outside of the diversion channel minor changes to existing conditions may occur. The inlets to the diversion channel will be designed to maintain the existing 1-percent floodplain. The design of the inlets could result in minor drainage benefits for frequent events, such as rainfall events. During operation of the diversion channel, flows will generally stay below existing ground up to the 1-percent chance event; this will allow the diversion to receive local drainage. Once the existing ground level is exceeded, local drainage into the diversion could be limited or stop in some cases, however it is not anticipated that flood levels outside of the diversion would exceed existing conditions.

Figure 65 - 10-percent chance event (10-year) upstream extent—existing vs. LPP

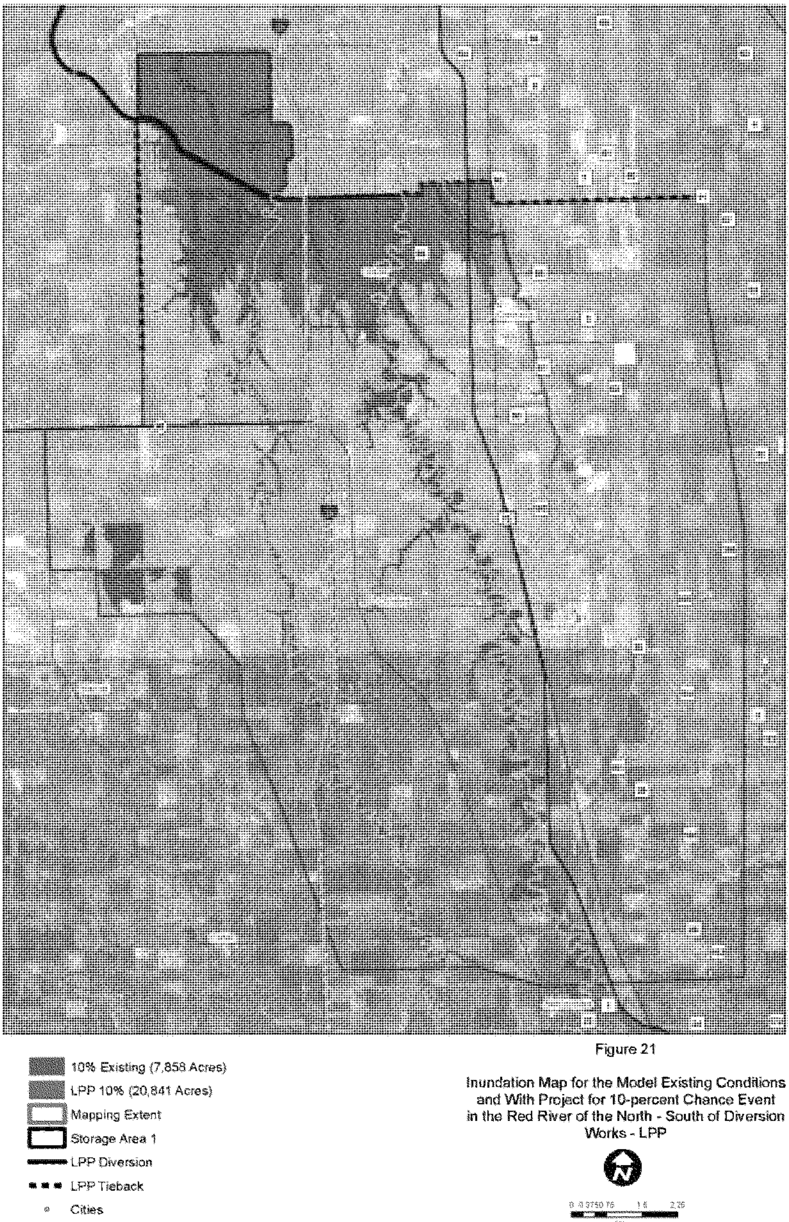


Figure 66 – 10-percent chance event (10-year) downstream extent to Drayton—existing vs. LPP

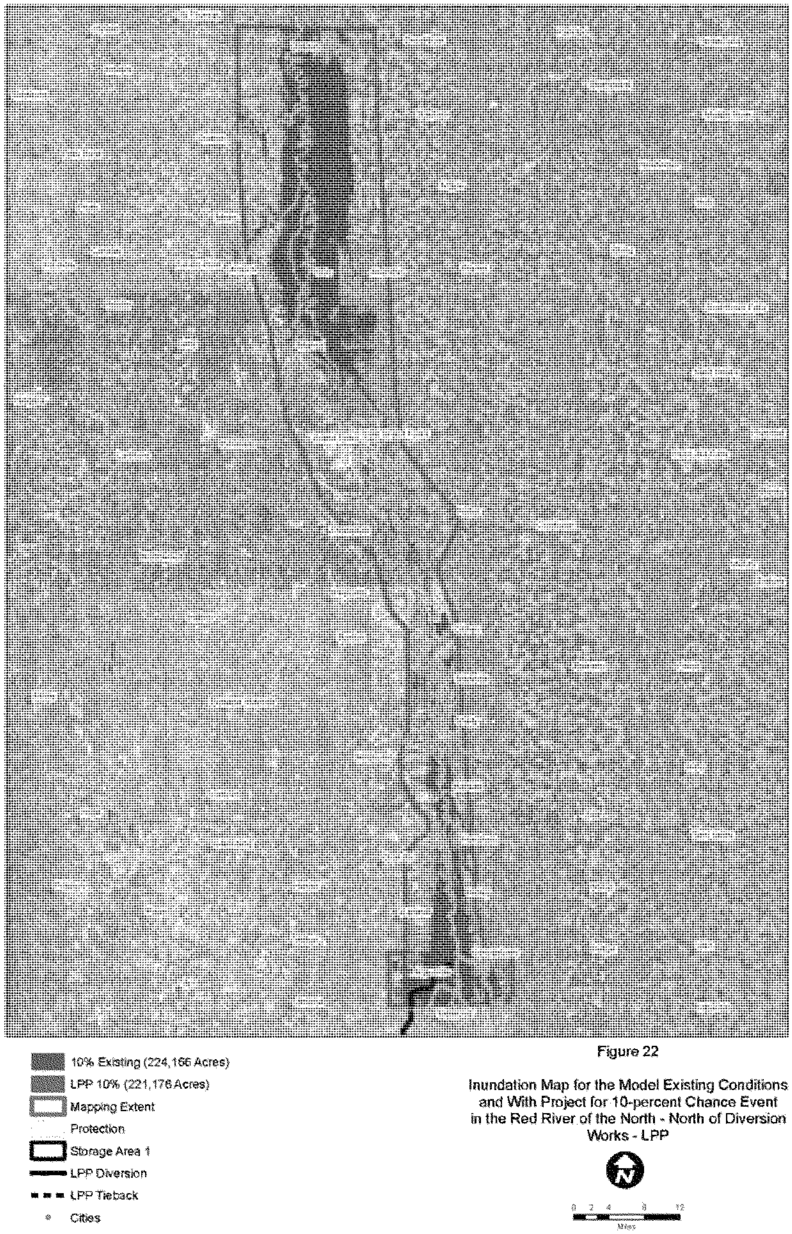


Figure 67 – 2-percent chance event (50-year) upstream extent—existing vs. LPP

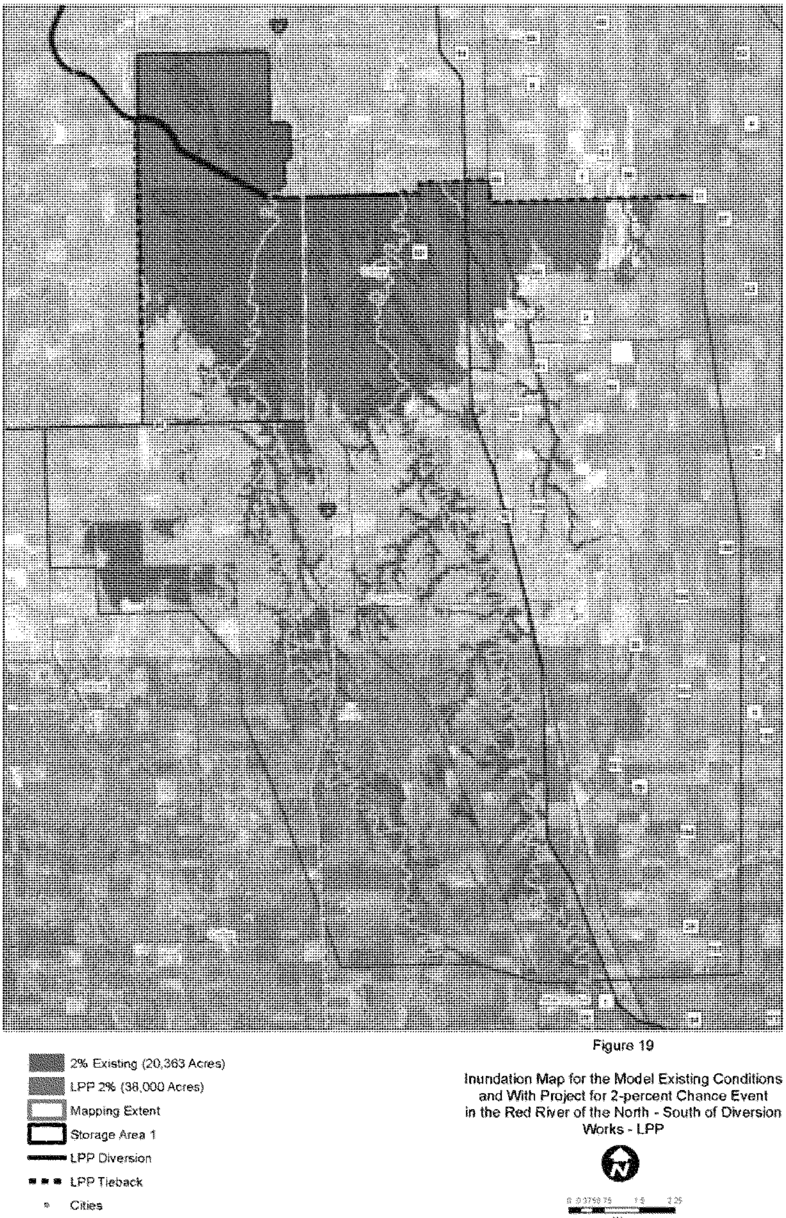


Figure 68 – 2-percent chance event (50-year) downstream extent to Drayton—existing vs. LPP

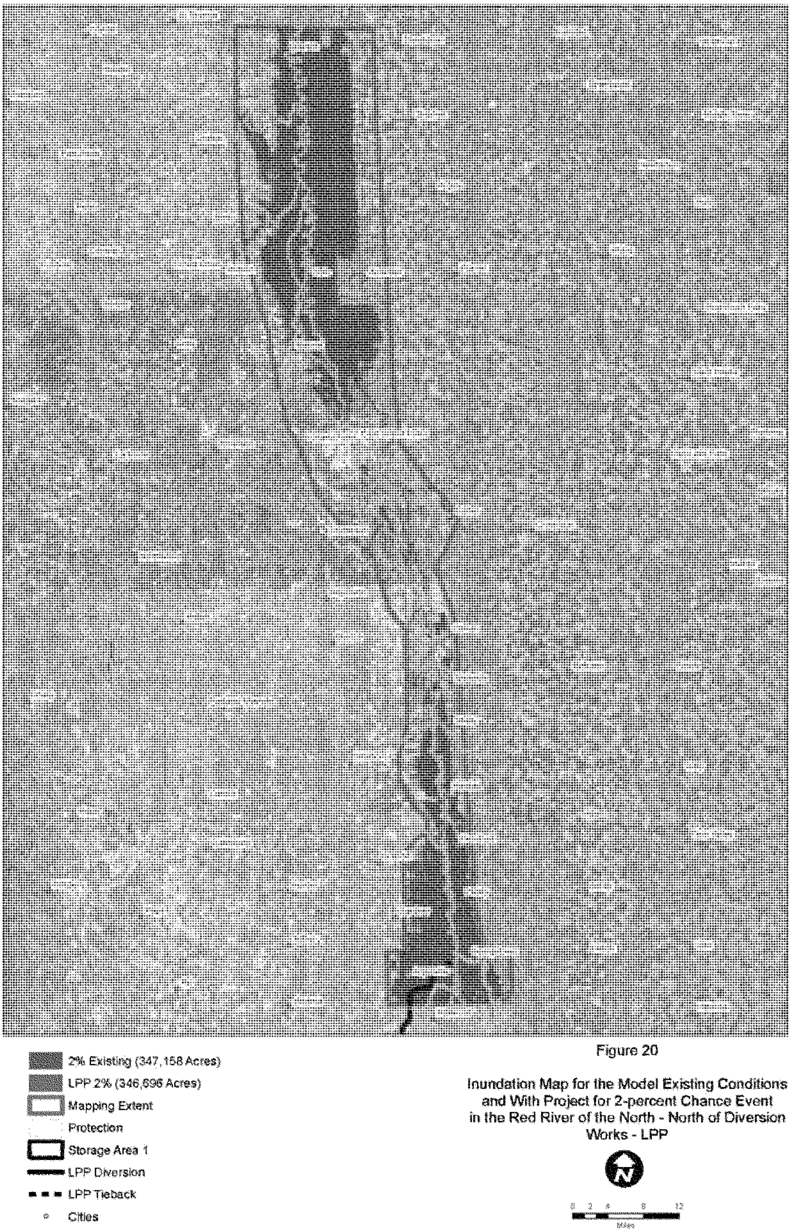


Figure 69 – 1-percent chance event (100-year) upstream extent—existing vs. LPP

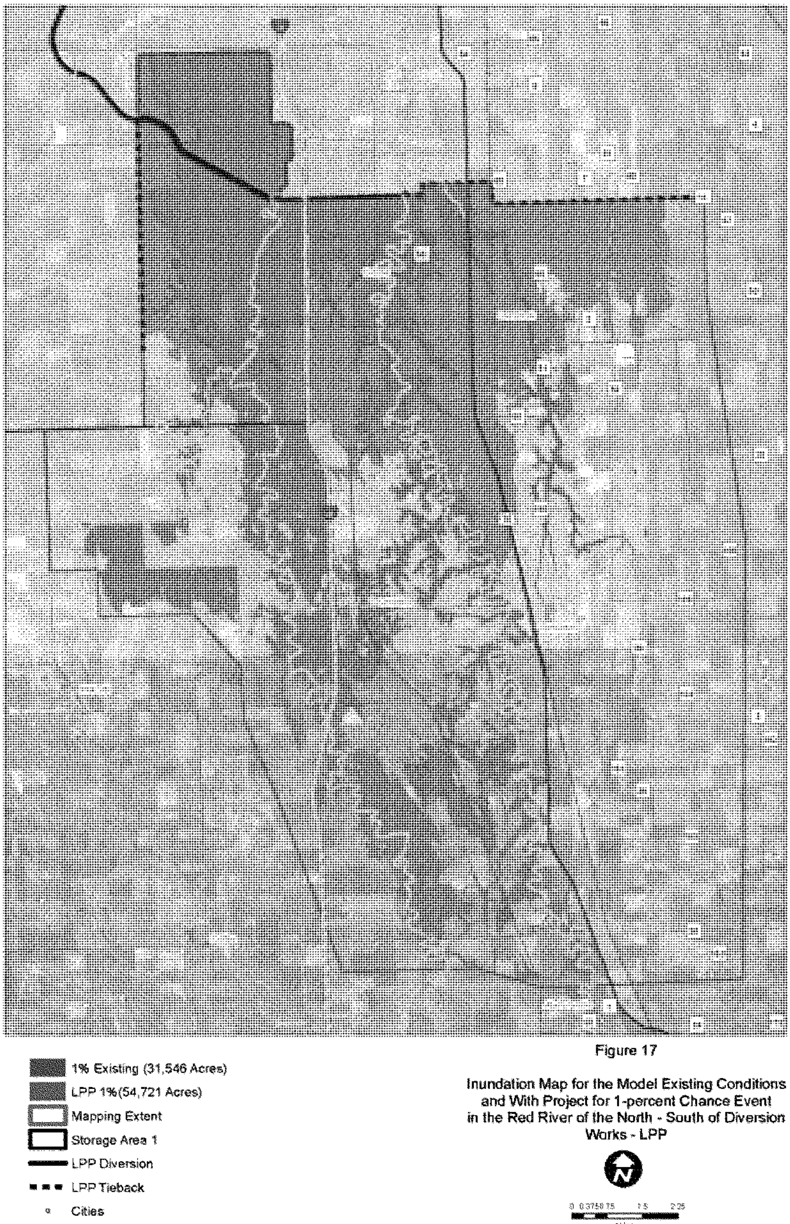


Figure 70 – 1-percent chance event (100-year) downstream extent to Drayton—existing vs. LPP

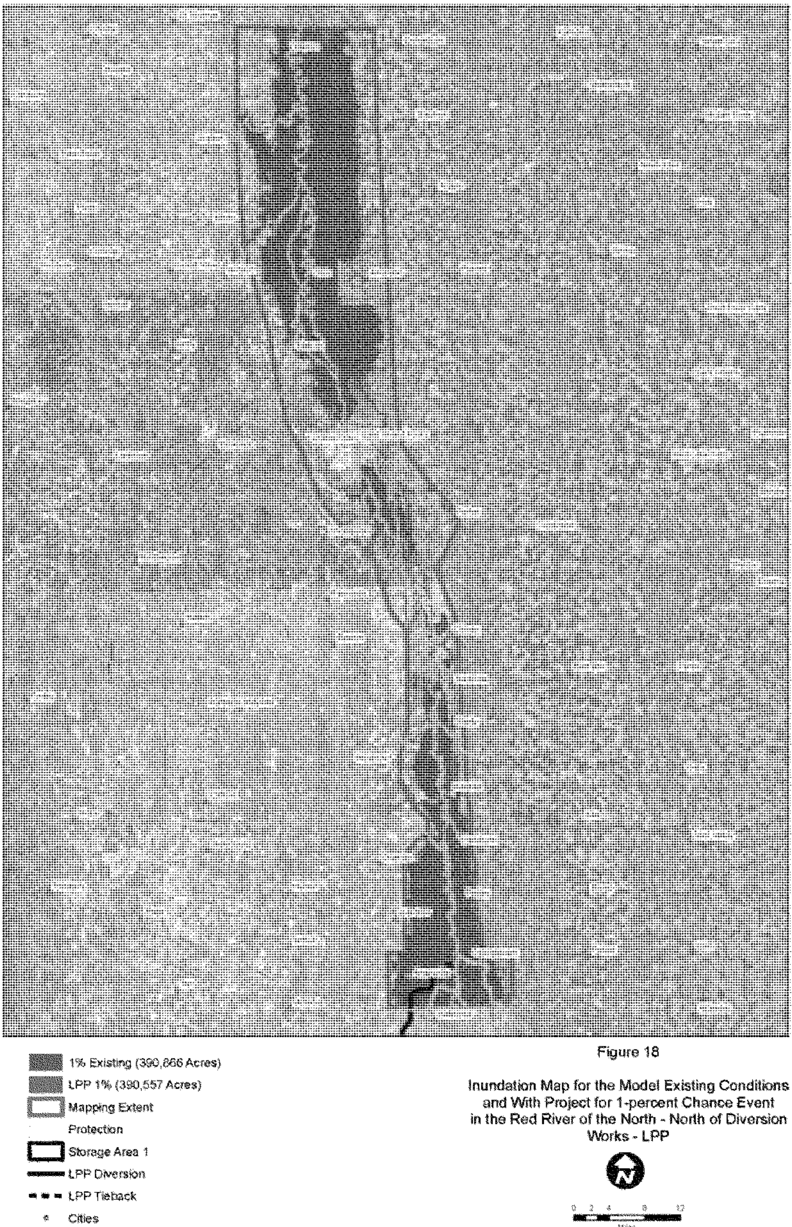


Figure 71 - 0.2-percent chance event (500-year) upstream extent—existing vs. LPP

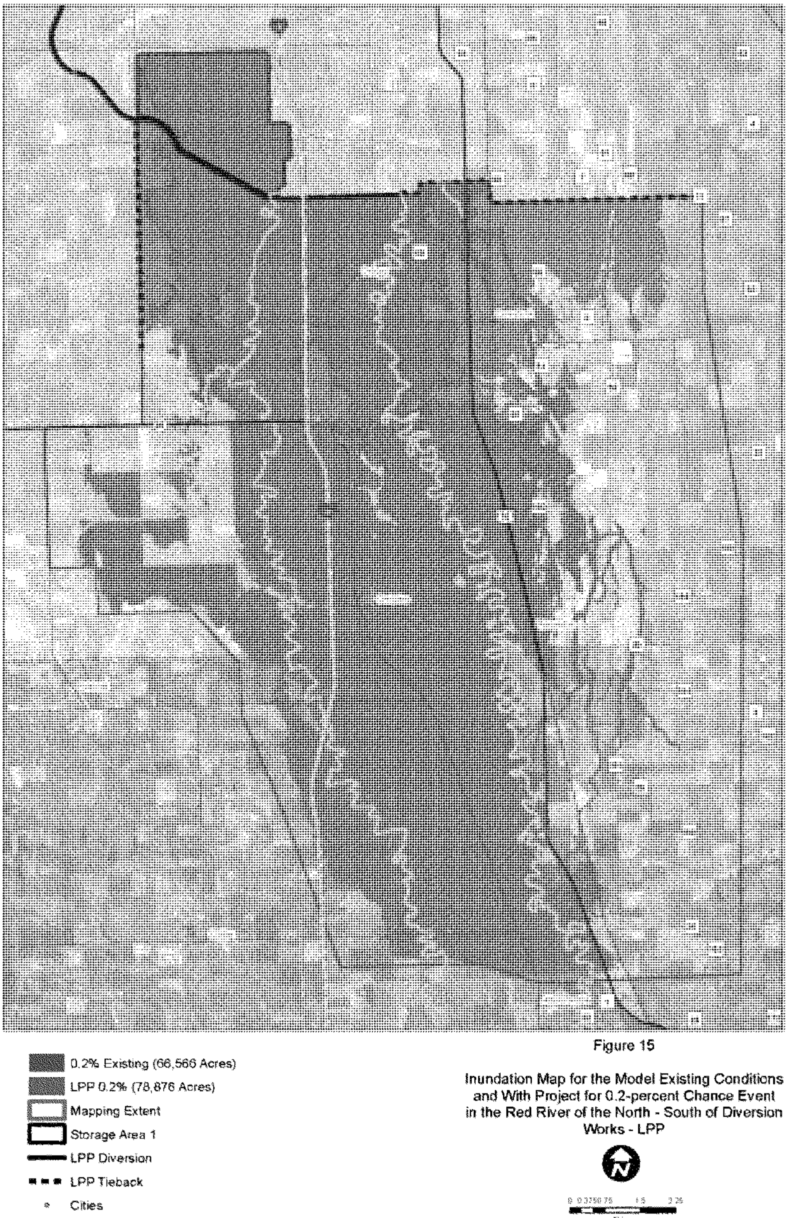


Figure 72 - 0.2-percent chance event (500-year) downstream extent to Drayton—existing vs. LPP

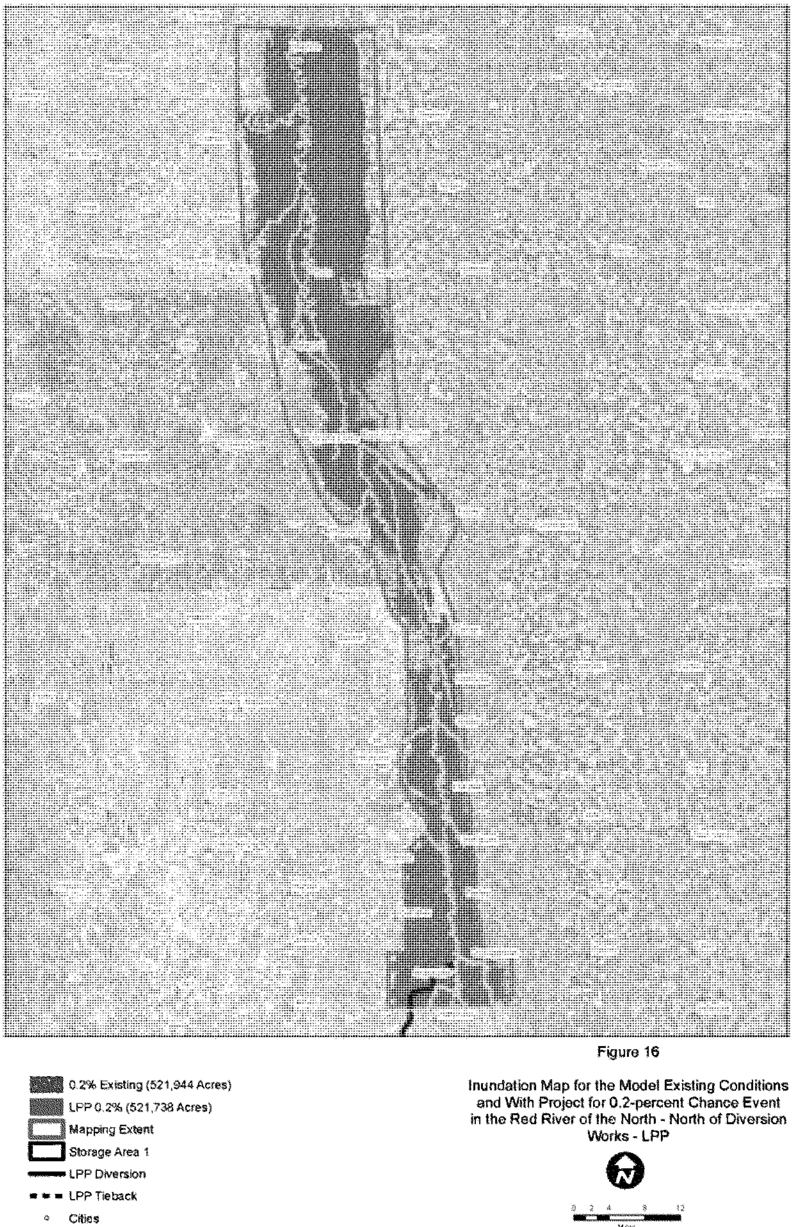


Figure 73 - Upstream staging area additional depth with project – 1 percent chance event

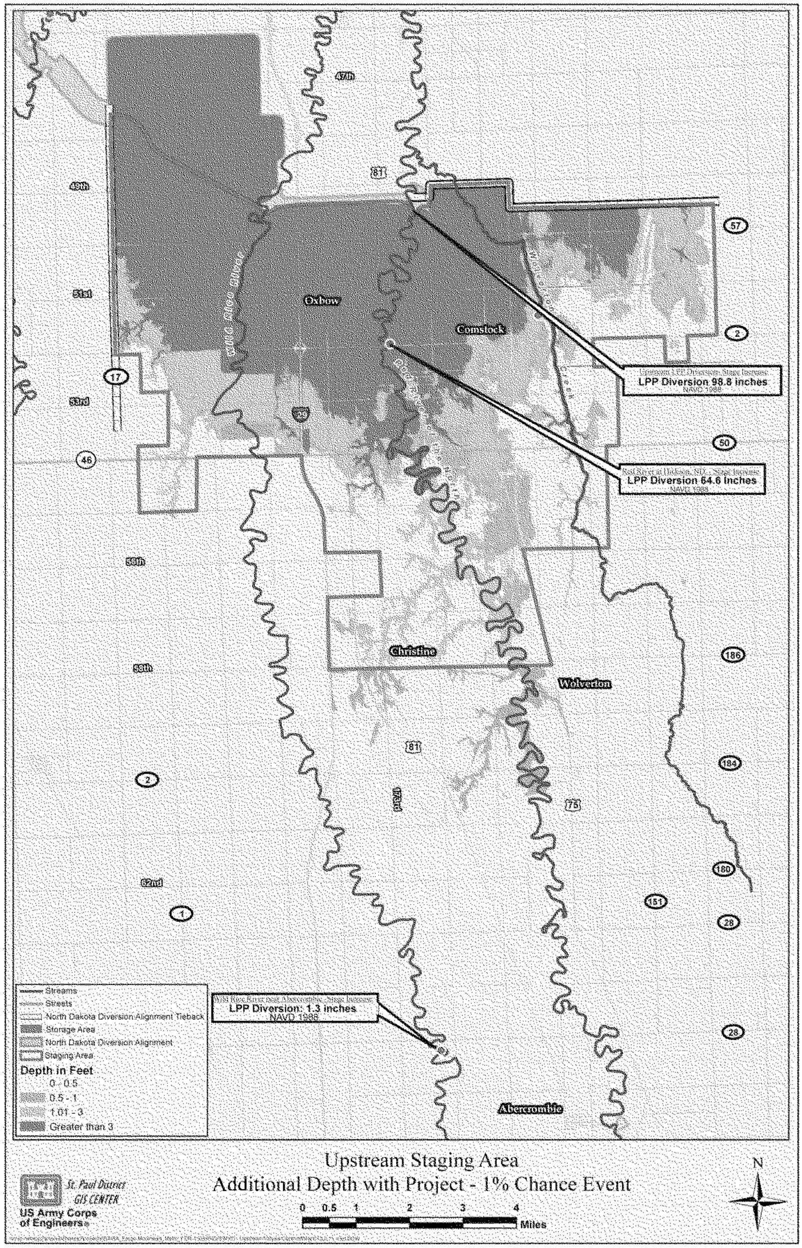
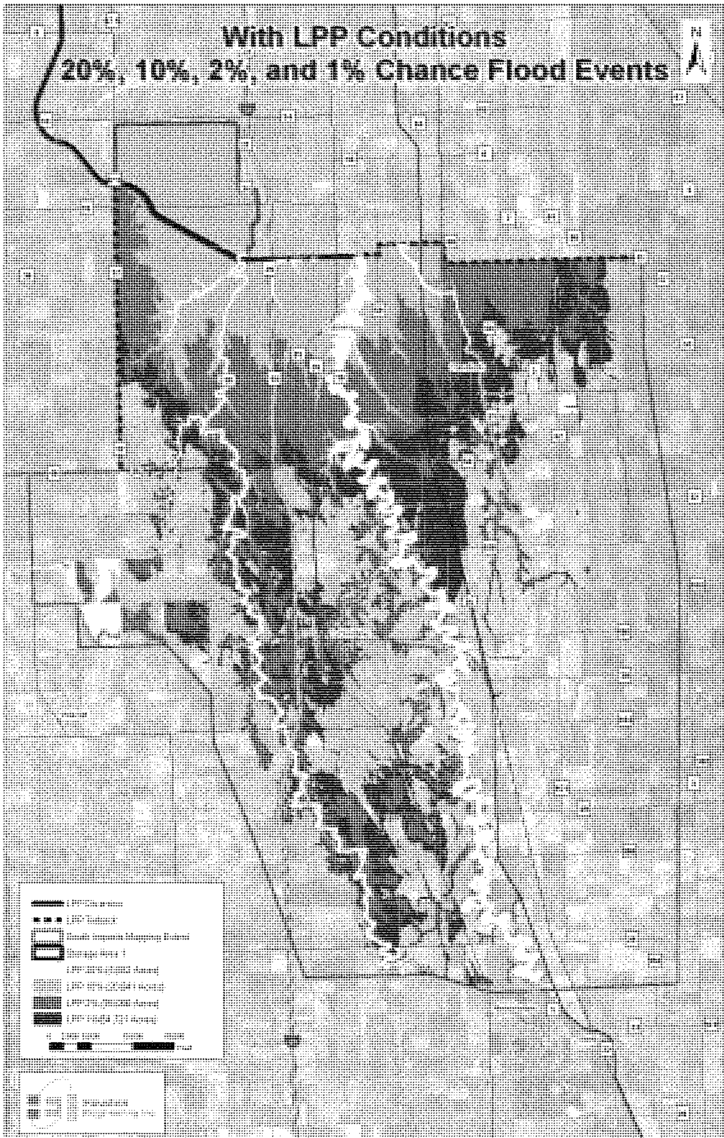


Figure 74 - Upstream staging impacts for the 20 percent, 10 percent, 2 percent, and 1 percent chance events



5.2.1.5 Wetlands
A team of Corps wetland scientists assessed wetlands using off-site review methodology, followed by field review to ground-truth the off-site review and to perform representative wetland delineations and functional assessments. Wetland areas were identified using all available sources of information, including National Wetlands Inventory (NWI) mapping, soil survey mapping, USGS topographic maps, LiDAR imagery and multiple years of aerial photography. Antecedent precipitation was analyzed prior to each field review, as well as in relation to dates of aerial photography.

On July 1-2, 2010, the team reviewed both diversion corridor alignments to ground-truth the images and signatures identified on aerial photography as wetland areas. Antecedent precipitation for this field review was normal. Following this ground-truthing field review, the team completed the off-site mapping of all the wetlands within the study area. On July 27-30, the team returned to the study area to complete representative delineations and functional assessments, using the Corps of Engineers Wetland Delineation Manual (Manual), the Regional Supplement to the Corps Delineation Manual: Great Plains Region (Version 2.0), March 2010 (Supplement) and Minnesota Routine Assessment Methodology for Evaluating Wetland Functions (MnRAM), Version 3.3, refining the extent of wetlands within all off-site mapped areas. Antecedent precipitation prior to the final field review at the end of July 2010 was wet. The field work is documented in the "Fargo-Moorhead Metropolitan Area Flood Risk Reduction Project Determination" that is in appendix F.

The types of wetlands found within the corridors for the diversion channel alternatives, in accordance with Eggers & Reed (corresponding Cowardin Classification), are farmed seasonally flooded basin (PEMAf), fresh wet meadow (PEMB), shallow marsh (PEMC), floodplain forest (PFO1A) and shallow open water (PUBH). Floodplain forest wetlands were assessed for the Upland Habitat/Riparian Habitat section of this document and were not analyzed further for this section of the document, except for a brief description of functions. Table 45 below provides a breakdown, by type, of the total acreage of non-forested wetlands found for the FCP, LPP and ND35K. Figure 75 - Figure 85, show the locations of wetlands found for the FCP, LPP and ND35K.

Table 45 - Wetlands directly impacted by construction, with the exception of forested wetlands and in-stream wetlands acreages which are addressed separately.

Wetland Type	**North Dakota/LPP Corridor and Storage area Levees (Total area: 8054 ac)**	**North Dakota/ND35K Corridor (Total area: 6560 ac)**	**Minnesota/FCP Corridor (Total area: 6415 ac)**
Approximate total acres hydric soil	7250	5900	4040
Farmed, seasonally flooded basin	790	720	800
Wet meadow	140	120	50
Shallow marsh	50	40	50
Shallow open water	10	10	10
Total Wetland Acreage	990	890	910
% Wetland	12%	14%	14%

For Wetland Type definitions see Appendix F

Farmed, seasonally flooded basins in the study area are lower lying areas within agricultural fields from which shallow surface drains have not effectively removed surface water or saturation, therefore wetland hydrology remains long enough during the growing season. Many of these lower lying areas are themselves shaped into shallow field ditches channeling water from the remainder of the fields. Prior to European settlement of the study area, this lake plain (see soils discussion below) was dominated by wetland communities. These seasonally flooded basins are generally the remnants of the historic wetland areas.

Wet meadows may have surface water only early in the growing season and are typically saturated into the latter part of the summer. Wet meadows in the study area are dominated by reed canarygrass (*Phalaris arundinacea*), sedges, other grasses and forbs.

Shallow marshes typically have at least 6 inches of surface water throughout the growing season, and in the study area are dominated by cattail species (*Typha sp.*). Many field-side and roadside ditches traverse the area (see discussion of lateral effect below), and, where these areas also exhibit the characteristics of wetlands, they were classified as wet meadows or shallow marshes, depending upon the predominant vegetation and depth of water present.

In the ND35K and LPP alignment corridor, there are a few shallow open water basins, where standing water from 3 to 6 feet is normally present throughout the growing season. Most of these areas appear to be excavated ponds, some of which are used as stormwater retention basins, except for one small pond adjacent to the Wild Rice River. There is one shallow open water area near the FCP alignment just south of Interstate 94, which is a MnDOT mitigation area/stormwater basin.

Soils of the study area are primarily associated with lake plains and floodplains and formed in calcareous clayey lacustrine sediments. They are very deep, poorly and very poorly drained and slowly permeable. Slope gradients are commonly less than 1 percent but range from 0 to 6 percent, with steeper slopes associated with side slopes of streams. Runoff is negligible depending on slope. Saturated hydraulic conductivity is slow. A system of surface drains associated with road ditches, section lines and agricultural fields remove surface water from most soils. A seasonal high water table is at the surface to about 3.0 feet below the surface at some time during the period of March through July. The water table is 1.0 foot above the surface to 2.0 feet below the surface at some time during the period of February through August in lower lying depressional areas. (Source: Official Soil Series Descriptions. USDA, NRCS. 2010).

As mentioned in the preceding paragraph, a system of surface drains is present. Subsurface drainage such as tiling is not a common practice in the areas near the LPP and ND35K alignment, but is more common in the areas near the FCP alignment. Except for lower lying depressions, the drains remove surface water from most soils. Given the slow permeability of the soil, the drains have a reduced effect on lowering the water table. Nonetheless, the lateral drainage effect of surface drains on the water table was estimated using the van Schilfgaarde equation (Hydrology Tools for Wetland Determination. Engineering Field Handbook, Chapter 19. USDA, NRCS. August, 1997 and Hydrology Tools for Wetland Determination, Minnesota Supplement 19-57 to the Engineering Field Handbook. USDA, NRCS. April, 2005). To calculate lateral effect, variables such as ditch depth were estimated during field visits and soil parameters were estimated from the WEB Soil Survey. The "T" factor, or the duration of time for the drain to lower the water table one foot below the soil surface, was set at 14 days. Fourteen days is the required duration for determining wetland hydrology on hydrologically altered sites (Supplement to the Corps of Engineers Wetland Delineation Manual: Great Plains Region version 2.0). Lateral effect information was used in determining the extent of wetlands remaining on the landscape.

The surface drainage was initiated during European settlement of this area in order to make production of agricultural crops possible, and much of the land within the proposed diversion alignments is currently used for agricultural purposes. Although the surface drainage systems (ditches) make agricultural production possible in many areas in most years, the ditches have not effectively removed all of the hydrology from the surface, and many wetlands remain. These wetlands are farmed through in most years, and crops are often lost or suffer stress in lower lying depressions. Wetlands in this area have been significantly impacted by the agricultural practices, including the drainage of the natural hydrology, plowing of the soils and loss of the natural vegetation. The wet meadow, shallow marsh and floodplain forest areas, although usually left untouched by direct planting, have been affected by the agricultural runoff containing eroded soils and agricultural chemicals.

Functional Assessment Analysis
As stated above, part of the assessment of impacts to aquatic resources as a result of the proposed Red River diversion channels included completion of MnRAM analyses on representative sites within the diversion channel corridors. Due to time constraints and similarity of the majority of wetlands within the study area, Corps staff chose not to assess functionality on every area determined to be wetland. Instead, at least one randomly-chosen area representative of each type of wetland found within the diversion channel corridors was assessed for typical functionality. (Note: Although forested wetlands were assessed in the Riparian Habitat section below, a short statement about forested wetlands is included below.)

Wetlands found within those active agricultural lands provide limited levels of functionality within this environment due to the extensive drainage and overall alteration that has taken place in the region. The majority of wetlands within the review area are depressional field ditches and depressional isolated wetlands of the farmed, seasonally flooded basin type (see field photos in Appendix F). Due to the extensive drainage systems, these seasonally flooded wetlands generally provide "Low" function for *Maintenance of Hydrologic Regime* and *Maintenance of Wetland Water Quality*. When drainage moves water off the landscape more quickly than in a natural setting, wetlands do not have the opportunity to continually feed the downstream system with a supply of water, and the agricultural impacts directly affect the wetland's ability to maintain water quality within the basin. Because the wetlands are found within agricultural fields, they also function at a low level in *Maintenance of Character of Wildlife Habitat*, and A*esthetics/Recreation/Education/Cultural benefit*. Without natural vegetation, there is no opportunity to provide wildlife habitat and the wetlands do not provide any aesthetic or recreational 'value' to the human landscape.

The depressional wetland areas within agricultural fields do, however, generally provide "Moderate" to "High" functionality for *Flood/Storm-water Attenuation* and also for *Downstream Water Quality*. Those wetlands that have been shaped into shallow field ditches provide a moderate level of flood/stormwater attenuation because they are able to hold some of the water on the landscape for at least a short period of time. Shallow isolated depressional wetlands provide a high level of functionality for flood/stormwater attenuation, as they are able to hold the water on the landscape until it can infiltrate, rather than run off to nearby over-stressed water courses. All field wetlands provide a moderate level of functionality for protection of downstream water quality because they are able to filter at least some of the nutrients from the agricultural runoff before the water enters nearby waterways. The depressional wetlands generally do not provide any level of function for amphibian or fish habitat or shoreline protection, therefore functional analysis was not applicable in these areas.

Fresh wet meadows and shallow marsh wetlands that are not actively farmed within the diversion channel corridors provide similar levels of functionality as described above, with a few noted differences. For *Maintenance of Wetland Water Quality*, wet meadows and shallow marshes provide a moderate level of functionality. With natural vegetation present, such as cattails (*Typha sp.*), the water quality within the wetland is treated through the plants' uptake of nutrients. These wetlands also provide a moderate level of wildlife habitat because of the natural vegetation.

In the ND35K and LPP diversion channel corridor, there are two areas classified as shallow open water. One is a constructed storm water retention pond at the west edge of Prairie Rose, and the other is located adjacent to the Wild Rice River surrounded by a forested floodplain on private property. In the Minnesota diversion corridor, there is one constructed stormwater retention pond/mitigation wetland just south of Interstate 94. The constructed water resource functions as it should at a high level for flood/stormwater attenuation as well as protection of downstream water quality, and it functions at a low to moderate level for most other functions, such as amphibian and wildlife habitat and maintenance of hydrologic regime. The shallow open water basin adjacent to the Wild Rice River performs at a low to moderate level for all measured functions. While it can provide a moderate level of flood/stormwater attenuation and water quality protection, its outlet to the Wild Rice River is too low and not constricted, minimizing its ability to retain water. This basin provides a moderate level of wildlife and fish habitat, providing protection for water fowl and spawning habitat for fish.

Floodplain forest wetlands provide a moderate level of functionality for maintenance of the hydrologic regime, as they are able to gradually feed the river system with water stored in the soils following flood events. The forested floodplains also provide a moderate level of shoreline protection and floodwater resistance by increasing the surface roughness, resulting in an increased detention of high flows and reduced erosion, and ultimately reducing peak flows downstream. In addition, the forest canopy provides the wetland with the opportunity to provide a moderate level of function for wildlife habitat.

5.2.1.5.1 No Action Alternative

There are numerous wetland restoration programs in place within the study area but many are slowed by cost and/or land availability. The objectives of the wetland restoration programs include flood risk management, improving water quality, and wildlife and recreation opportunities. Due to increasing pressure to either urbanize or improve drainage on cropland, it is anticipated that wetland acreage will either remain the same or decrease within the study area.

5.2.1.5.2 FCP

The construction of the FCP will cause a direct loss of wetlands due to either excavation of the wetlands within the diversion channel or placement of spoil in the wetlands adjacent to the diversion channel. The FCP alignment could directly or indirectly impact approximately 910 acres of wetlands (Table 45), which does not include floodplain forest acreage or abandon channel acreage; these acreages are being accounted for in other sections of this document. Impacts were calculated by using the footprint of the FCP diversion channel. This area included the footprint of the 25 mile long diversion channel and spoil piles for this plan. This analysis also included the tieback levees and extension channels that would be constructed for this plan.

Wetlands could also be lost indirectly through the construction of the diversion channel. The natural drainage patterns could be changed due to the placement of the spoil adjacent to the diversion channel. These changes could either be: 1) the drainage pattern to the wetlands is cutoff, eliminating the recharge of the wetland, or 2) a drainage pattern is created to the diversion, allowing the wetland to drain. In addition, the diversion channel creates a lower hydraulic potential area toward which water will try to seep. The seepage into the diversion channel could cause the wetlands adjacent to the diversion channel to dry up. These acreages would be minor due to the low permeability of the soils in the study area and are included in the total impacts delineated.

The risk associated with the indirect loss of wetlands is low for two reasons. First, the spoil could possibly be placed such that it would not affect the natural drainage pattern, either away from or into the wetlands. Second, the flow of water from the wetlands into the diversion channel through the subsurface will be minimal due to the impervious nature of the surrounding soils. It is likely that seasonal fluctuation and precipitation patterns will have a greater effect on the wetlands than the subsurface drainage. The indirect loss of any wetlands is expected to be minimal and would be offset by the creation of wetlands within the diversion channel bottom. The impacts to wetlands are not considered significant.

Examination of aerial photography shows that the area had considerably more wetlands prior to conversion to agriculture. The direct loss of the wetlands is certain and unavoidable within the footprint of the channel and spoil piles. Wetland acres that will be adversely affected by diversion channel construction will be offset by the creation of wetlands within the diversion channel bottom. Features that will be used to facilitate the creation of wetlands will include meandering the low flow channel; constructing rock riffles in locations to create ponding; and other features developed during the design of the project. Vegetative species would be planted that are appropriate to temporarily flooded wetlands; types of species to be planted could include Broad-leaved arrowhead, sweet flag, water plantain, rice cut-grass, reed manna grass, river bulrush, as well as other native species native to this region. A low flow channel is a channel that is typically in the center of a larger channel which is sized to handle small flows from drains, ditches or groundwater. The low flow channel would be approximately a 10 foot wide by 3 foot deep channel located in the middle of the larger diversion channel, and could meander back and forth within the 400 foot wide diversion channel bottom. The area used for the mitigation will include the entire 400 foot bottom width of the diversion channel as well as a several hundred foot prairie swale buffer up the side slope of the channel. The opportunity for inter-agency partnerships to develop areas for improved habitat would be explored with the non-federal sponsors, interested federal, state and local agencies and interest groups during preparation of plans and specifications for the project.

Figure 75 – Wetlands along FCP diversion channel.

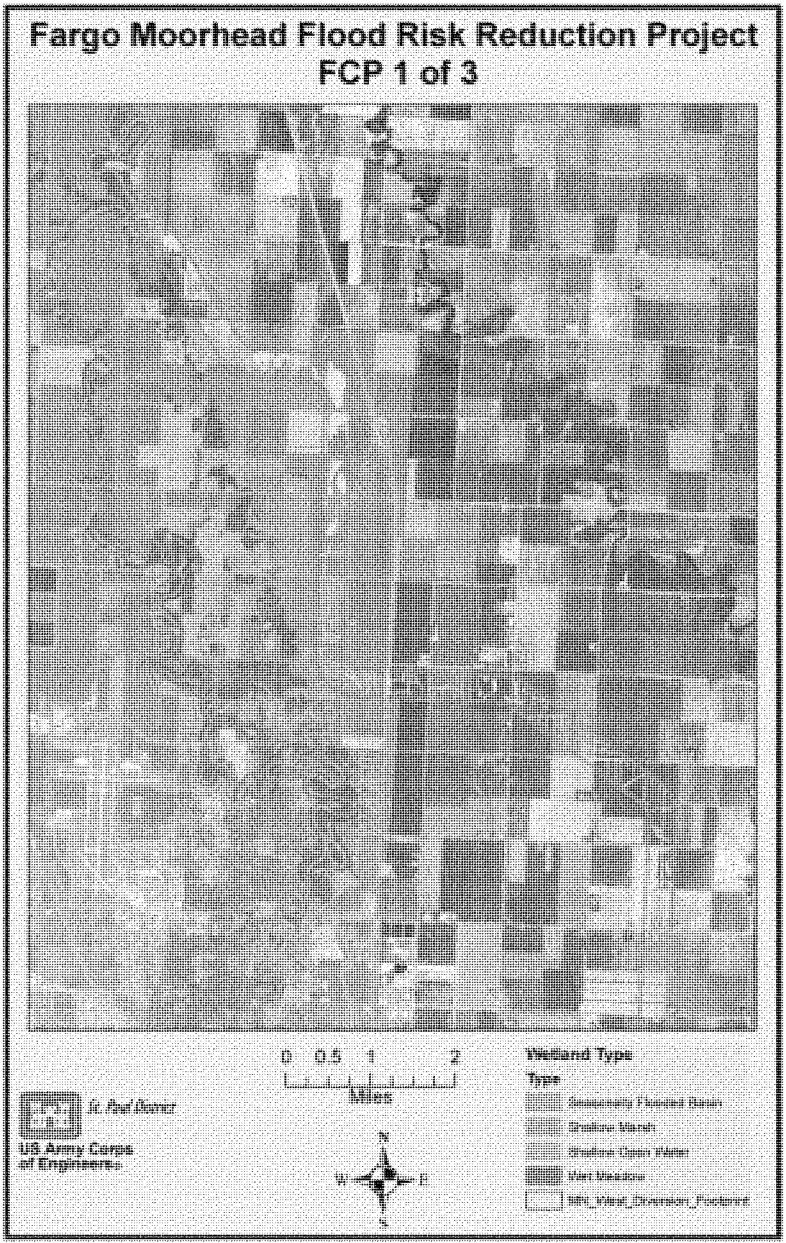


Figure 76 - Wetlands along FCP diversion channel.

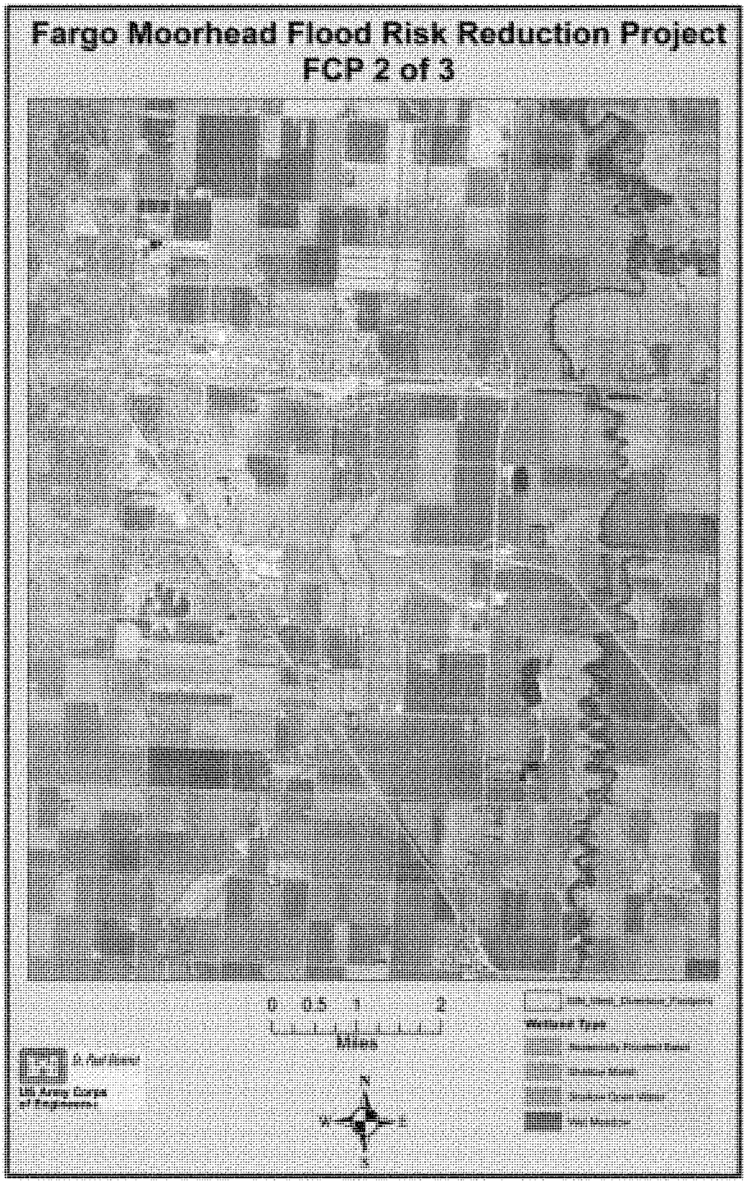
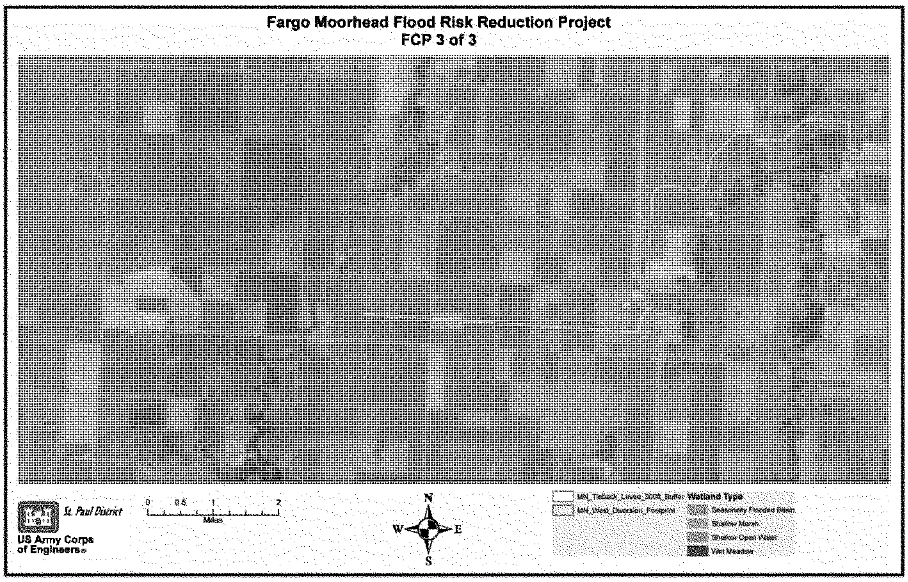


Figure 77 - Wetlands along FCP diversion channel and tie-back levees.



5.2.1.5.3 LPP and ND35K

The construction of the LPP or ND35K plan will cause a direct loss of wetlands due to excavation of the wetlands within the diversion channel, placement of spoil in the wetlands adjacent to the diversion channel, and levees for the respective plan. The ND35K alignment could directly impact approximately 890 acres of wetlands, while the LPP could impact approximately 990 acres of wetlands (Table 45). An additional 117 acres of floodplain forest and 46 acres of stream or riverine channel will be impacted for both alternatives, but these acreages are covered under different sections within this document. Impacts were calculated by using the footprint of the North Dakota alignment diversion channel. This area is the 36 mile long diversion channel and spoil pile for both plans. This analysis also includes the tie-back levees for both plans and the levee around the storage area for the LPP (Figure 82 - Figure 85). The tie-back levee that extends into Minnesota will be slightly longer for the LPP (Figure 84), which will impact more wetland acres. There is also an additional tie-back levee along County Rd 17 that is included for the LPP and not necessary for the ND35K (Figure 84).

Wetlands could also be lost indirectly through the construction of the diversion channel. The natural drainage patterns could be changed due to the placement of the spoil adjacent to the diversion channel. These changes could either be: 1) the drainage pattern to the wetlands is cutoff, eliminating the recharge of the wetland, or 2) a drainage pattern is created to the diversion, allowing the wetland to drain. In addition, the diversion channel creates a lower hydraulic potential area toward which water will try to seep. The seepage into the diversion channel could cause the wetlands adjacent to the diversion channel to dry up. These acreages would be minor due to the permeability of the soils in the study area and are included in the total impacts delineated.

The risk associated with the indirect loss of wetlands is low for two reasons. First, the spoil could possibly be placed such that it would not affect the natural drainage pattern, either away from or into the wetlands. Secondly, the flow of water from the wetlands into the diversion channel through the subsurface will be minimal due to the impervious nature of the surrounding soils. It is likely that seasonal fluctuation and precipitation patterns will have a greater effect on the wetlands than the subsurface drainage. The indirect loss of any wetlands is expected to be minimal and would be offset by the creation of wetlands within the diversion channel bottom.

Similar to the FCP, an examination of aerial photography shows that the area had considerably more wetlands prior to conversion to agriculture. The direct loss of the wetlands is certain and unavoidable within the footprint of the channel and spoil piles. Wetland acres that will be adversely affected by diversion channel construction will be offset by the creation of wetlands within the diversion channel bottom. Features that will be used to facilitate the creation of wetlands will include meandering the low flow channel; constructing rock riffles in locations to create ponding, and other features developed during the design of the project. Vegetative species would be planted that are appropriate to temporarily flooded wetlands. A low flow channel is a channel that is typically in the center of a larger channel which is sized to handle small flows from drains, ditches or groundwater. The low flow channel would be approximately a 10 foot wide, 3 foot deep channel, with 4:1 foot slopes for a top width of 34 feet. This channel would be located in the middle of the larger diversion channel, and could meander back and forth within the maximum of 250 foot wide diversion channel bottom. Additionally, for the LPP the footprint of the 4,450 acre storage area will have some wetland function after project construction. This area will be inundated with water at approximately the 28-percent chance event; this inundation as well as inundation from rainfall will increase wetland function over these acres. The opportunity for inter-agency partnerships to develop areas for improved habitat would be explored with the non-federal sponsors, interested federal, state and local agencies and interest groups during preparation of plans and specifications.

Additional wetland impacts from the LPP and ND35K are possible because the existing channels downstream of the diversion for the Lower Rush River and the Rush River will be abandoned. This will not cause a loss of wetlands but a change in function, because the channels will still have some overland flow enter into the channels. These areas will remain wetland. Acreages associated with the change of wetland function for the Lower Rush River and Rush River will be offset by the channel design within the diversion channel.

The selected plan will not appreciably change the migration patterns of migratory birds. This issue was discussed with the U.S. Fish and Wildlife Service and it concurs with this assessment. Also, according to the Federal Aviation Administration's Advisory Circular 150/5200-33B Hazardous Wildlife Attractants On or Near Airports, the agency recommends a distance of five miles between the edge of an airport and any hazardous wildlife attractant. The closest the proposed diversion channel would get to Hector International Airport property is slightly over 6 miles.

Figure 78 - Wetlands along ND35K diversion channel alignment

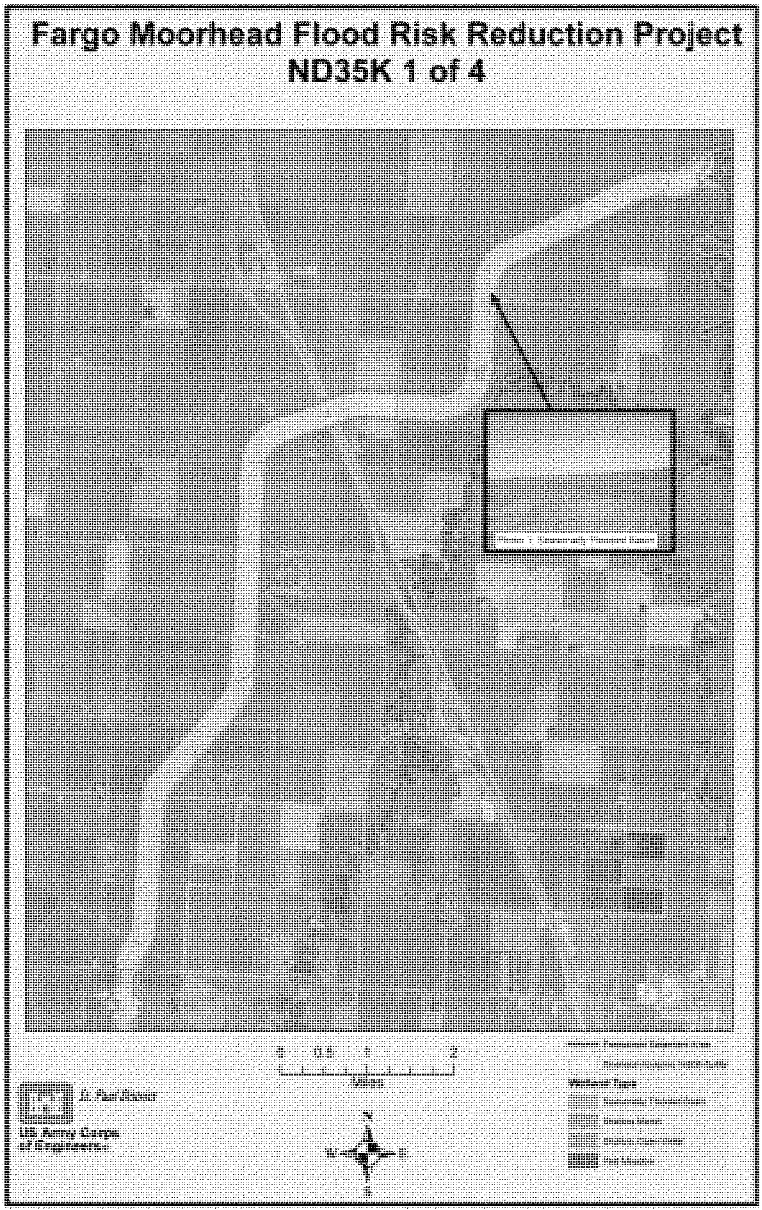


Figure 79 - Wetlands along ND35K diversion channel alignment

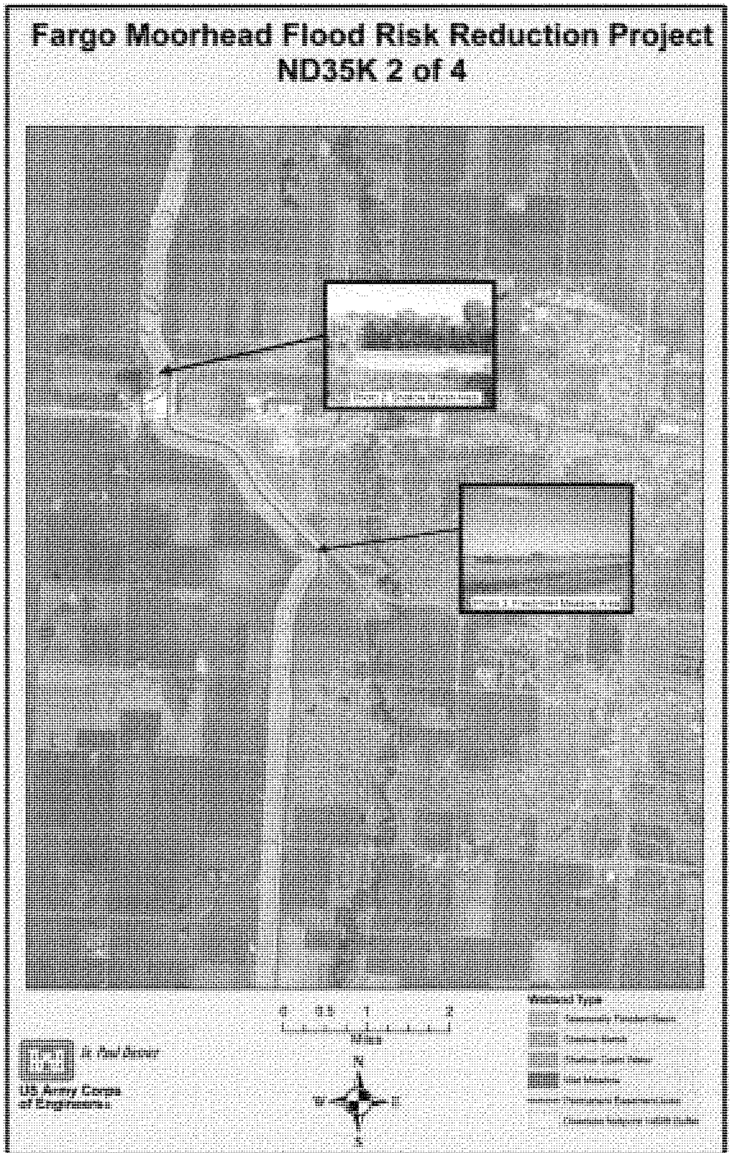


Figure 80 - Wetlands along ND35K diversion channel alignment

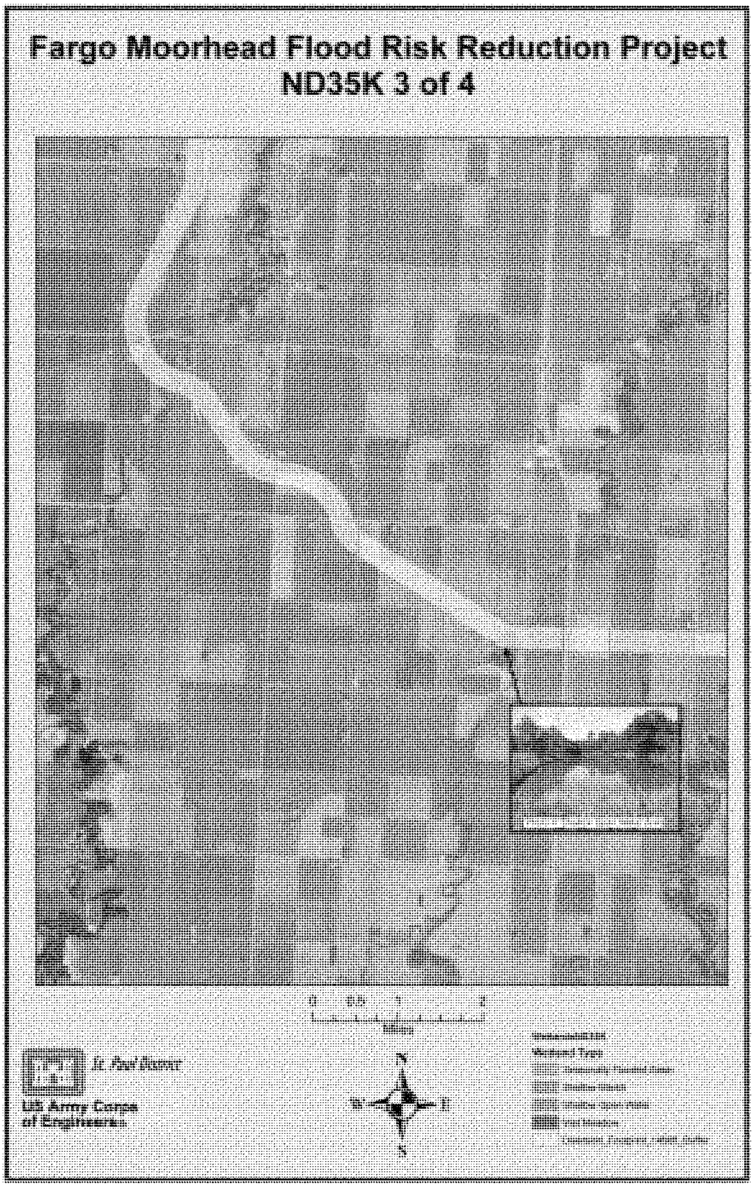


Figure 81 - Wetlands along ND35K diversion channel alignment

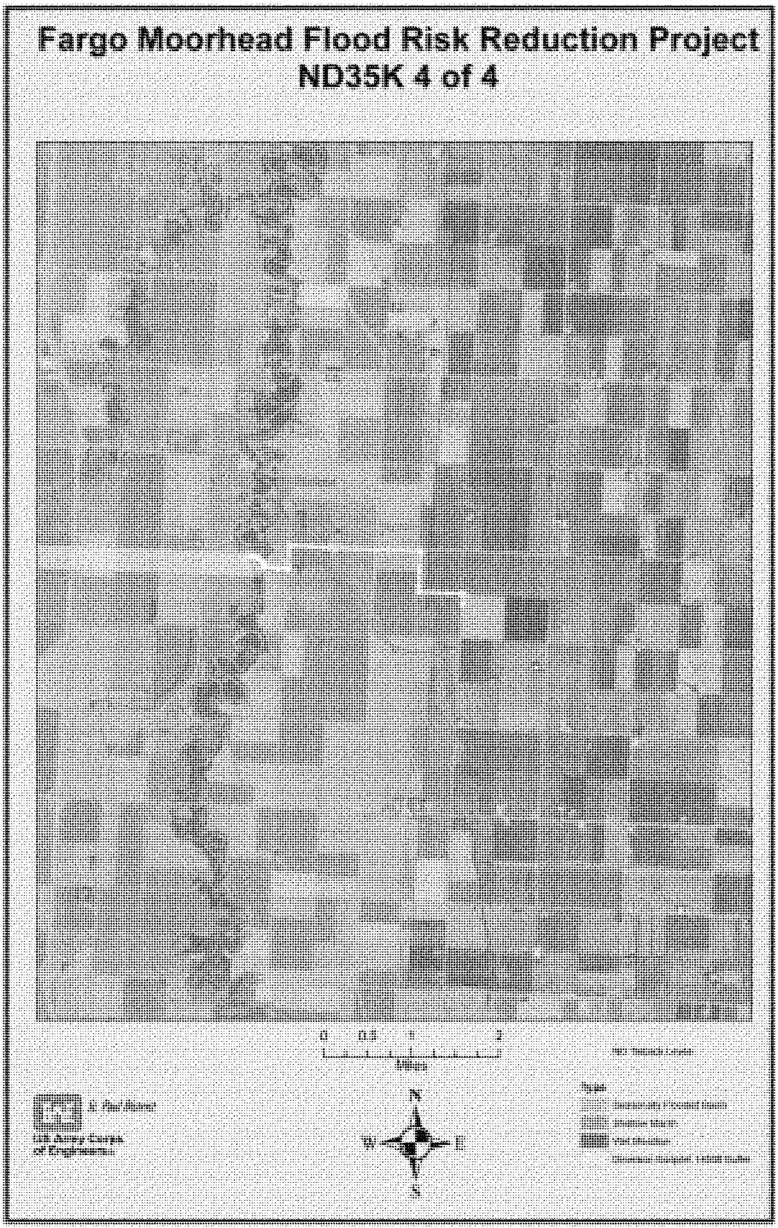


Figure 82 - Wetlands along LPP diversion channel alignment

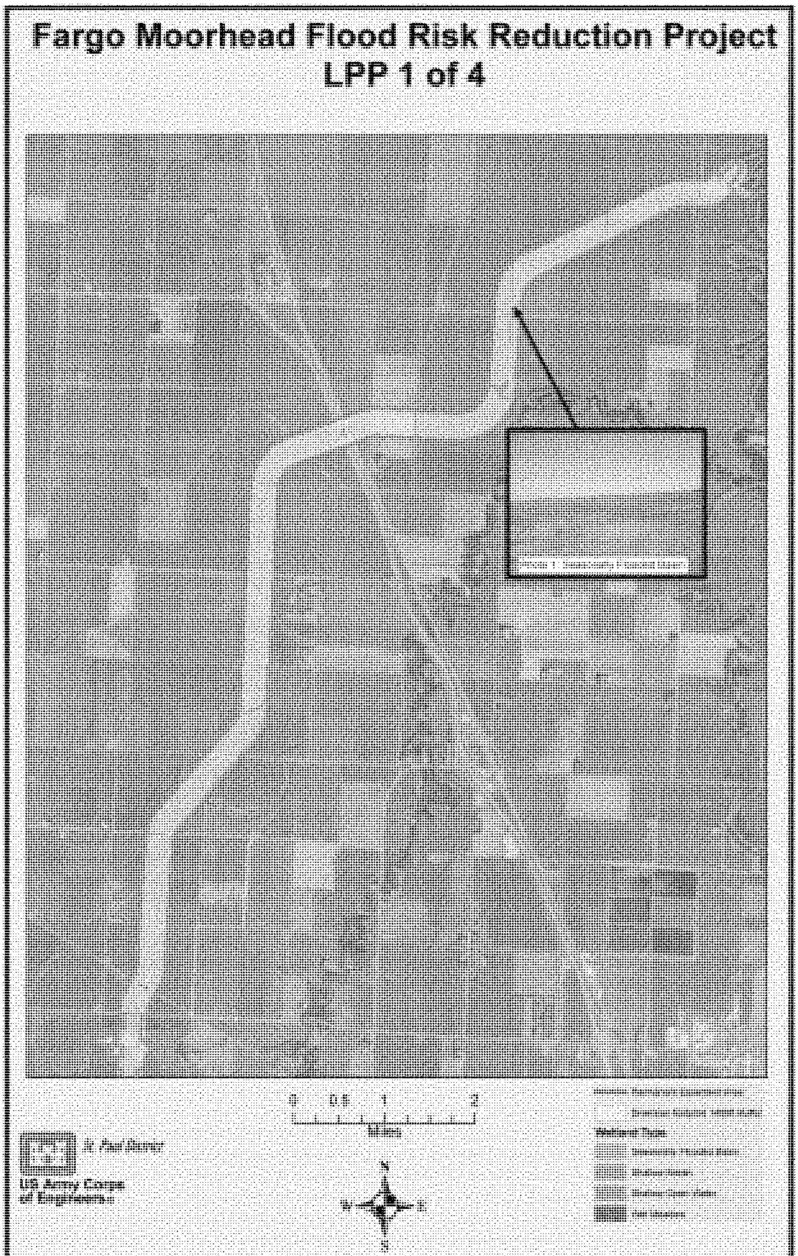


Figure 83 - Wetlands along LPP diversion alignment channel

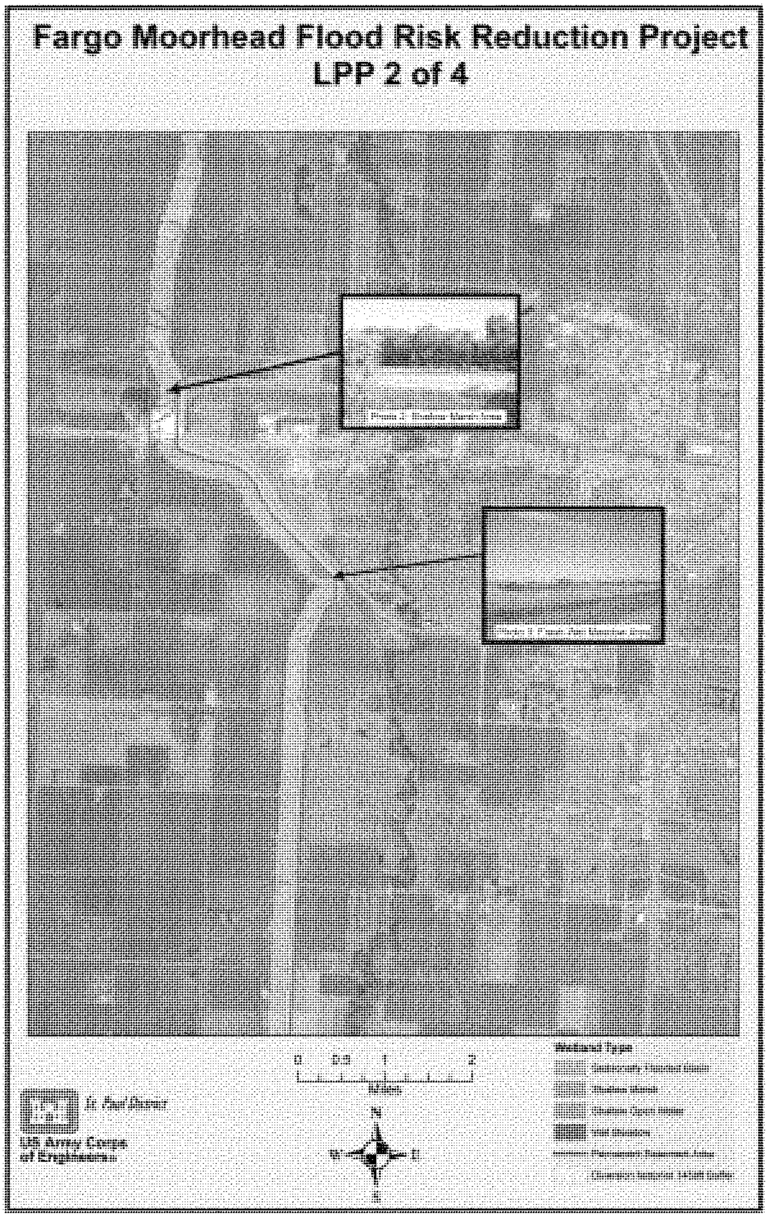


Figure 84 - Wetlands along LPP diversion channel alignment

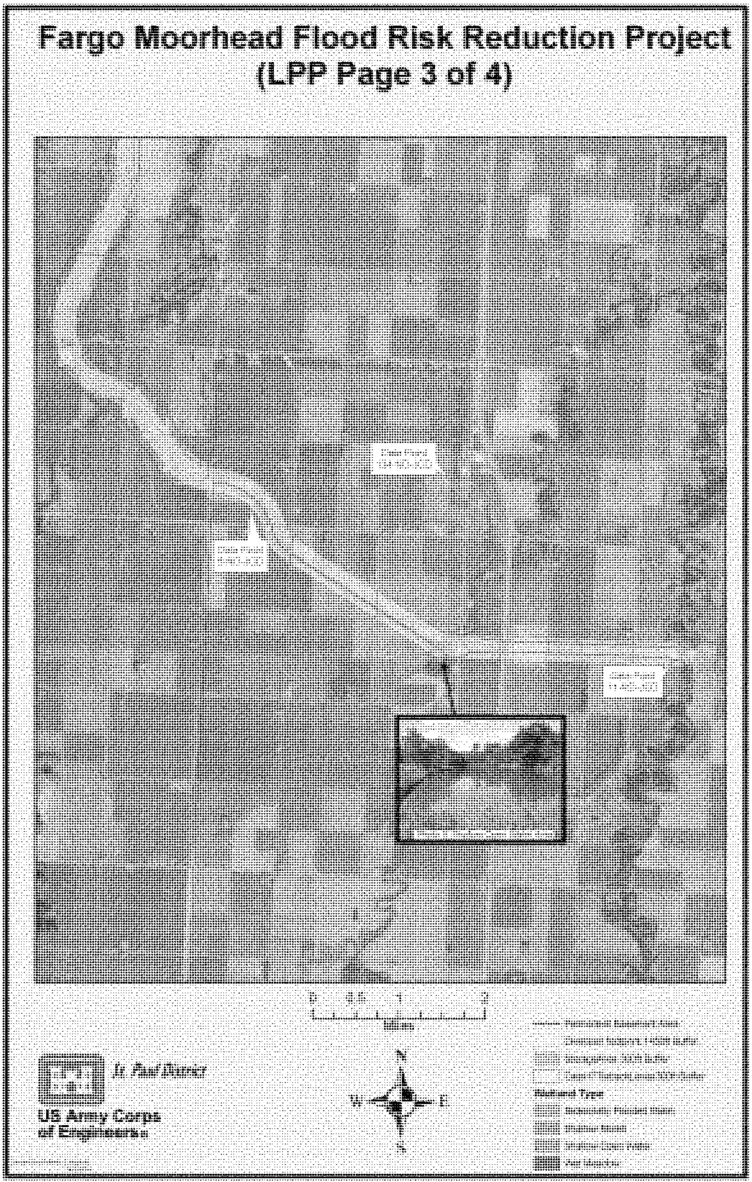


Figure 85 - Wetlands along ND35Kdiversion alignment channel

5.2.1.6 Shallow Groundwater

All of the diversion channel alternatives would have a similar effect on shallow groundwater. The shallow groundwater table is defined as the locally observed groundwater table near the ground surface, typically located within the first 15 feet below the ground surface. The groundwater table fluctuates seasonally, depending on the soil type, precipitation and climatic conditions experienced throughout the year or years. Periodic fluctuation of the groundwater table is assumed to occur even without the construction of a diversion channel. Groundwater is not considered a significant source for water in the area due to the relatively low permeability of soils and the low volume of water expected to flow through these soils.

Under the conditions reasonably anticipated, the flow of the shallow groundwater should be "downhill" or toward the area of lower hydraulic potential. After the excavation of a diversion channel is completed, the "downhill" or lowest potential area should be the bottom of the diversion channel. This may lower the groundwater table near the diversion channel but, at most, only to the depth of the excavated diversion channel. The lateral extent of the lowered groundwater table would likely be confined to areas immediately adjacent to the diversion channel including the spoil banks. Areas outside the extent of this would likely see very little to no change. The natural groundwater flow quantities through tight clayey soils would reasonably be expected to be relatively small.

A lowered shallow groundwater table could potentially reduce the capacity of shallow local wells that are recharged by the groundwater table. The risk to the shallow groundwater table as related to the proposed diversion is low because the anticipated area affected would be concentrated adjacent to the diversion channel. The lowering of the shallow groundwater table may cause consolidation of the surrounding soils and settlement of structures within the area affected. Only structures immediately adjacent to the proposed diversion channel would have the potential to settle. Since the area affected is not expected to extend beyond the channel and spoil piles it is unlikely that any structures remaining after construction would be impacted. If local shallow wells experience reduction in capacity, the depth of the well could be increased or an additional well be installed to mitigate for the reduced capacity. Wells and structures that are within the proposed footprint of the diversion channel would be removed or abandoned, while those immediately adjacent would be identified and monitored to quantify any impacts. Any impacts identified as the result of the construction and/or operation of the proposed diversion can be mitigated for.

5.2.1.6.1 Aquifers

All of the diversion channel alternatives would have a similar effect on aquifers. For the purposes of this report, aquifers in the study area are defined as pervious, water-bearing geological formations that are located at depth and covered by relatively impermeable formations. Aquifers may provide a major source of water and are assumed to have some amount of artesian pressures. The major aquifers in the study area are the Buffalo Aquifer in Minnesota and the West Fargo Aquifer in North Dakota. The most current subsurface geological model known is a 3-D model (Minnesota Geological Survey, 2005) that shows the majority of the Buffalo aquifer is over 1000 feet from the FCP channel. Measureable impacts to the aquifer with this separation are considered unlikely. Sandy beds within the lake clays may also be present along the alignment; verifying if and how they are hydraulically connected to the Buffalo Aquifer is on-going. Additional subsurface exploration in the spring and summer of 2010 along with an on-going review of existing data was used in an attempt to identify any sandy seams that may exist within the proposed diversion foot-print. To date no significant sandy seams have been identified and work remains on-going. The West Fargo Aquifer is somewhat more limited in aerial extent with conditions similar to these surrounding the Buffalo Aquifer. For these reasons measurable impacts are considered unlikely.

The first potential effect that construction of a diversion channel could have is the lowering of the artesian pressures in the aquifer. With the construction of the diversion channel, the seepage path length from the aquifer to the ground surface could be reduced approximately by the depth of the channel excavation. This reduced seepage path length and creation of a lower potential area may increase the flow of the water out of the aquifer. If the quantity of flow out of the Buffalo Aquifer (or any aquifer) is greater than the quantity of flow recharging the system, the artesian pressures can be reduced. The total volume of water available at a given time in the aquifer may be negatively impacted as well. The result of the lowered artesian pressures would be that more pumping would be necessary for private and municipal use.

The second potential effect of a diversion channel is that contamination of the aquifer could occur. The diversion channel excavation would reduce the length that contaminants would have to travel from the ground surface to the aquifer. However an aquifer under artesian pressure will have a positive pressure "outward" toward the diversion channel making it very difficult for potential contaminants to "migrate" against this pressure (away from the diversion) and towards the main portion of the aquifer. In the unlikely event of contamination the use of the aquifer as a source of water for domestic use could be restricted.

Due to the relatively impervious nature of the subsurface materials likely to be encountered along the route of any proposed diversion alternative, the flow of water from the aquifer due to artesian pressures and the migration of contaminates into the aquifer are minimized.

There are two mitigation/adaptive management measures that could be taken to reduce the risk of long term changes to the aquifer as a result of the proposed diversion. The first adaptive management measure would be to monitor the aquifer and the areas surrounding the diversion channel to see if the artesian pressures are being lowered after excavation of the diversion channel and what direction the water is flowing. If an impact to the aquifer was detected the second mitigation measure would be to place a more impervious buffer between the aquifer and the channel excavation to minimize the flow of water into the diversion channel or contaminants into the aquifer. If a pervious material was encountered during channel excavation, over-excavation of this material could be required and impervious fill placed to provide this buffer.

Additional data analyses and design refinements are recommended to verify alignment choices considering the local variations in the sub-surface geology. Based on the literature and initial exploration conducted for this study, there are some smaller scale sand and gravel beds that could be considered localized aquifers (groundwater instead of buried aquifers) if the beds are extensive enough to provide potable water for a residence or farmstead. The existence of these smaller localized aquifers needs to be matched with existing water wells to prevent or compensate for the loss of individual water wells along the alignment.

5.2.1.7 Fisheries and Aquatic Habitat

The discussion below addresses potential impacts of the various alternatives to fisheries resources and aquatic habitats. Because of similarities among alternatives, the discussion below will generally discuss effects common to all of the diversion channel alternatives, unless specifically noted. From a broad perspective, the FCP would have less substantial impacts to fisheries resources and aquatic habitat than the LPP or ND35K. Impacts to fisheries and aquatic habitat would be more substantial with the LPP or ND35K due to the project affecting an additional five tributaries. The LPP has additional impacts, relative to the ND35K, due to upstream staging of water to alleviate downstream water level impacts.

5.2.1.7.1 Direct Footprint Impacts

5.2.1.7.1.1 Red River Footprint Impacts

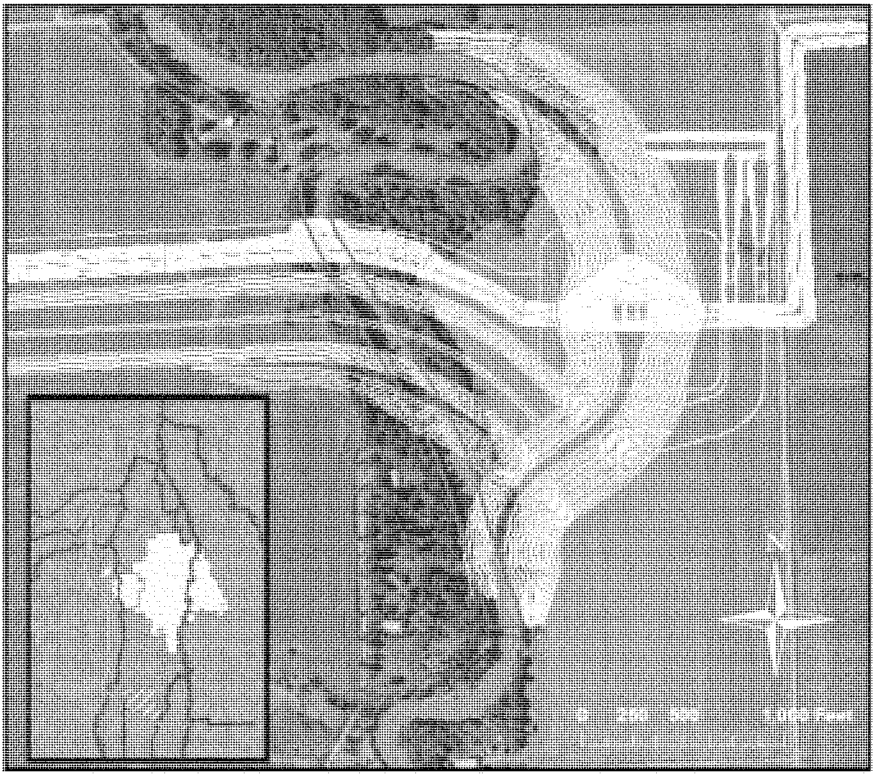
A concrete Red River control structure would be constructed for each of the three diversion channel alternatives. The exact location of the structure is not yet known but would be different between the North Dakota alignment and the Minnesota alignment. However, all alternatives would generally have similar footprint impacts. The control structure, including its operation, is described in Section 3.7.

Because of logistical challenges and construction risks, the likely construction method is to build the control structure “in the dry” adjacent to the Red River. Following completion, a new channel would be excavated and flow permanently routed through the new control structure.

To assess footprint impacts, aerial photos were reviewed within GIS to estimate the amount of riverine habitat directly affected. The upstream and downstream extent of the footprint were first identified based on likely feature boundaries. The channel area was then identified laterally up the bank to approximately a bankfull elevation, typically identified by the presence of trees. A polygon was then established to quantify the amount of riverine habitat impacted.

For the LPP and ND35K, the Red River control structure would result in the permanent abandonment of approximately 0.8 miles of Red River channel habitat. This would equate to approximately 14 acres of river habitat lost (Figure 86). The exact location and footprint impact could be further refined in future NEPA documentation. The North Dakota alignment is shown in Figure 86. By comparison, the FCP would result in abandonment of approximately 1.2 miles of channel, which would equate to 27 to 28 acres of river habitat. Riverine habitat would be created within the newly constructed channel through the control structure. However, it is not fully known to what extent the habitat created might replace that which is lost. As such, mitigation would be implemented to offset this impact. Potential mitigation measures are discussed in Section 5.5 and Attachment 6, Mitigation and Adaptive Management.

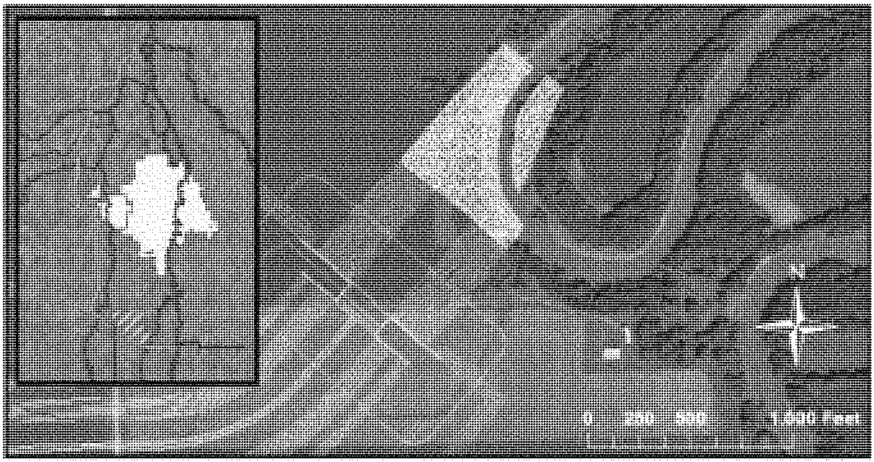
Figure 86 - Potential footprint impact area on the Red River for a diversion control structure for a North Dakota diversion alignment. Areas with channel abandonment or extensive modification area outlined in red.



For the downstream weir at the confluence of the Red River and the diversion channel, all three diversion channel alternatives would influence approximately 0.1 to 0.2 miles of Red River channel. This would equate to just under 3 acres of river habitat (Figure 87), with similar impacts amongst alternatives. The downstream weir will include adjacent riprap placement along both shorelines. Riparian habitat would be altered, and in-channel habitat could change with the presence of riprap. However, aquatic habitat would not be directly abandoned or lost. Benthic invertebrates would be buried where riprap is placed. However, such areas would be expected to recolonize. Although habitat could change, overall aquatic habitat quality adjacent to the downstream weir would not be expected to be substantially reduced with any of the diversion channel alternatives. Impacts to riparian habitat are discussed separately below.

Construction activities for any structures outlined here would result in temporary avoidance of the study area by fish during periods when in-water construction causes disturbance. However, this should be temporary, and would not be expected to have any meaningful long-term effect on Red River fisheries. Immobile biota (e.g., mussels and macroinvertebrates) would be lost during channel abandonment or placement of rock or other materials. However, mussels and invertebrates would likely recolonize new habitats.

Figure 87 - Potential footprint impact area on the Red River for the downstream weir at the confluence with the flood diversion, North Dakota diversion alignment. The Minnesota diversion alignment would join the Red River at a different location, but would have similar characteristics.

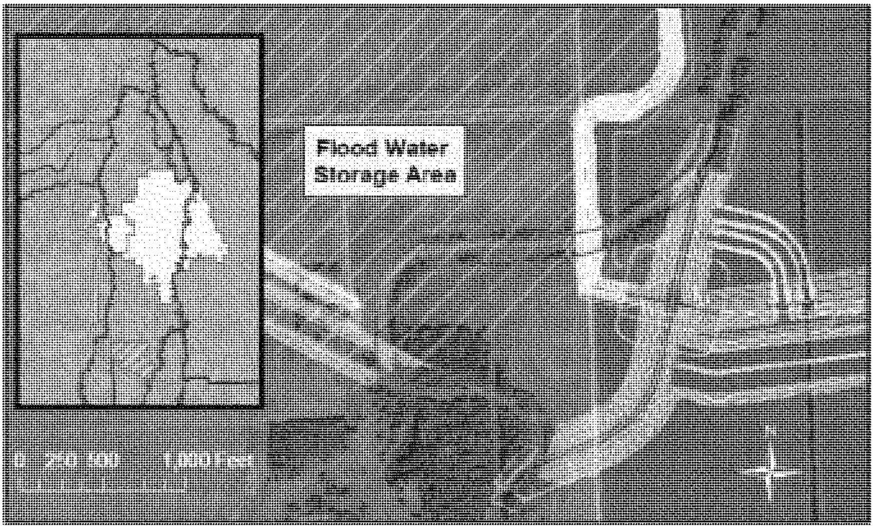


5.2.1.7.1.2 Wild Rice River Control Structures Footprint Impact

For the Minnesota alignment, the diversion channel will not cross any tributaries or other surface waters with notable fisheries resources. Thus, the FCP would not result in any direct significant impacts to tributary fisheries resources or habitat.

Both of the North Dakota diversion alternatives would have three different structures constructed at the confluence of the diversion channel and the Wild Rice River. This includes a control structure on the Wild Rice River just downstream of the confluence with the diversion channel; and two control weirs constructed on opposite banks of the Wild Rice River just upstream of the Wild Rice River control structure. These control structures, including their operation, are described in Section 3.7.

Figure 88 - Potential footprint impact area on the Wild Rice River. Areas with channel abandonment or extensive modification area outlined in red.



Similar to other structures, this structure also would be built "in the dry" adjacent to the existing Wild Rice River. Following completion, a new channel would be excavated and flow permanently routed through the new control structure.

The Wild Rice River control structure would result in the permanent abandonment of approximately 0.8 to 0.9 miles of riverine habitat. This would equate to approximately 12 acres of river habitat lost (Figure 88). The exact location and footprint impact could be further refined in future NEPA documentation if necessary. This impact would only occur with the two North Dakota diversion alternatives. Riverine habitat would be created within the newly constructed channel through the control structure. However, it is not fully known to what extent the habitat created might replace that which is lost. As such, mitigation would be implemented to offset this impact. Potential mitigation measures are discussed in Section 5.5 Mitigation and Adaptive Management and Attachment 6.

Construction activities for any structures would result in temporary avoidance of the study area by fish during periods when in-water construction causes disturbance. However, this should be temporary, and would not be expected to have any meaningful long-term effect on Wild Rice River fisheries. Immobile biota (e.g., invertebrates) would be lost during channel abandonment or placement of rock or other materials. However, invertebrates would likely recolonize new habitats.

5.2.1.7.1.3 Sheyenne and Maple River Tributary Aqueduct Footprint Impact
For both of the North Dakota alternatives, the diversion channel must cross the Sheyenne and Maple rivers. To accomplish this task, the Corps proposes to construct an aqueduct on each tributary that facilitates flow over the diversion channel. These structures are described in Section 3.7. The exact location, design and footprint, and corresponding impacts, could be further refined in future NEPA documentation if necessary. Both aqueducts would be designed for a channel width and depth similar to existing conditions at the chosen sites. Both structures would be a concrete channel, with a preliminary planned length of about 650 feet from the upstream to downstream edge of the concrete footprint.

Given the logistical challenges of constructing these aqueducts concurrently with the diversion channel, the Corps proposes to build these features adjacent to the tributaries. Similar to other features, these two tributaries would then be permanently diverted through the aqueducts.

Although the exact design has yet to be finalized, these tributary structures would impact several acres of aquatic habitat within both the Sheyenne and Maple rivers (Figure 89 - Figure 90). The Sheyenne River could see channel abandonment, or substantial alteration, to 0.8 to 0.9 miles of channel, which would amount to 8 to 9 acres of river habitat. The Maple River could see channel abandonment, or substantial alteration, to approximately 1.1 miles of channel, which would amount to 10 to 11 acres of river habitat.

The concrete portion of these new channels would have little aquatic habitat value. Riverine habitat would be created within the newly constructed channel leading into and out of the aqueducts. However, it is not fully known to what extent the habitat created might replace that which is lost. As such, mitigation would be implemented to offset this impact. Potential mitigation measures are discussed in Section 5.5 Mitigation and Adaptive Management and Attachment 6.

Figure 89 - Potential footprint impact area on the Sheyenne River. Areas with channel abandonment or extensive modification area outlined in red.

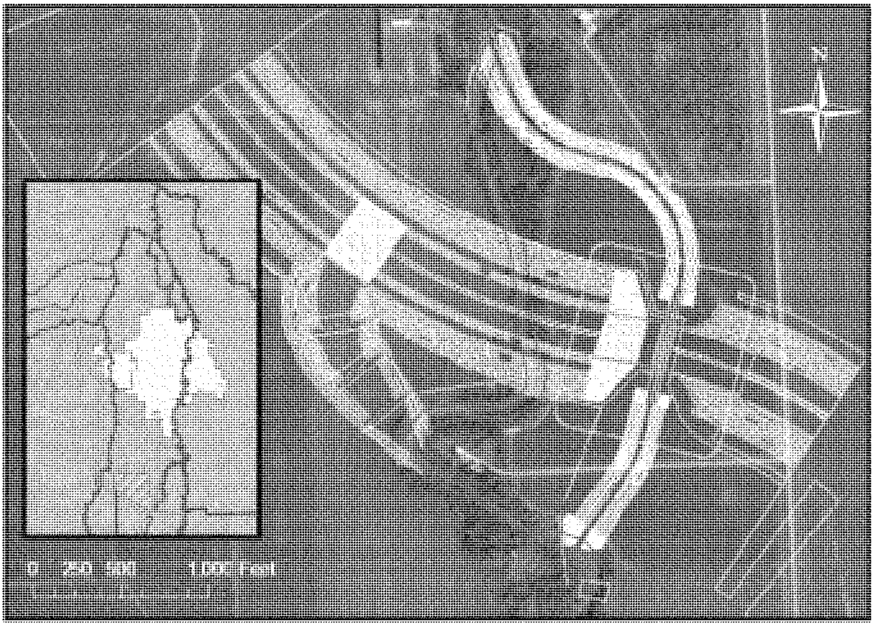
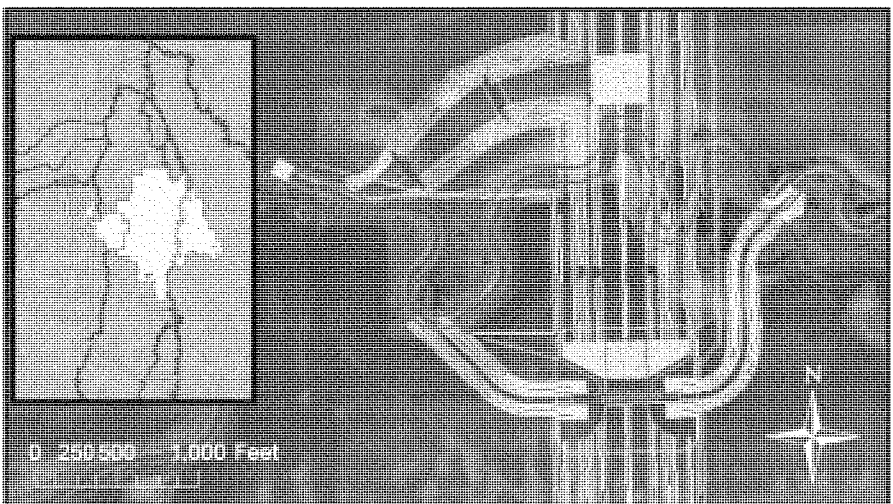


Figure 90 – Potential footprint area on the Maple River. Areas with channel abandonment or extensive modification area outlined in red



In addition to the footprint impact identified above for lost channel habitat, it is possible additional rock could be placed in and along the channel upstream or downstream for erosion protection or grade control. However, additional aquatic habitat would not be directly abandoned or lost.

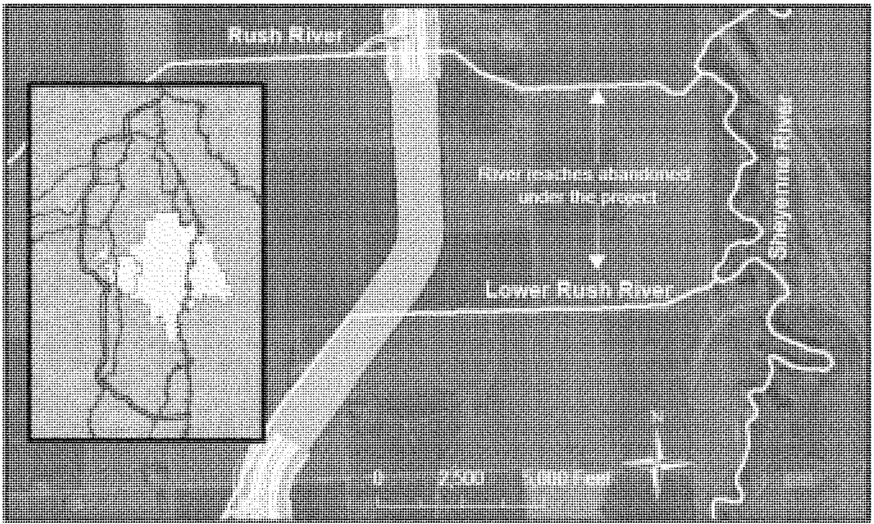
Construction activities for any structures would result in temporary avoidance of the study area by fish during periods when in-water construction causes disturbance. However, this should be temporary, and would not be expected to have any meaningful long-term effect on Sheyenne and Maple river fisheries. Immobile biota (e.g., invertebrates) would be lost during channel abandonment or placement of rock or other materials. However, invertebrates would likely recolonize new habitats.

5.2.1.7.1.4 Rush and Lower Rush Control Structures Footprint Impact
For both of the North Dakota alternatives, the diversion channel must also cross the Rush and Lower Rush rivers. Within the study area, these two rivers are channelized and appear to have limited habitat value. The Lower Rush River is intermittent, and at best will only be used seasonally as a fisheries resource. Given this, the Corps proposes to direct both of these tributaries into the diversion channel, as opposed to constructing aquaducts to convey flow over top of the diversion. In short, both tributaries would include a series of weirs to provide grade control to drop the tributaries from their current elevation down to the diversion channel. The base of the diversion channel, starting at the Lower Rush River, would include a meandering channel design along the remaining length of the diversion down to its confluence of the Red River. This channel would convey flows from these two tributaries, and provide river habitat in the bottom of the diversion channel.

The plan for the North Dakota alternatives would result in abandoning approximately 2.1 miles of the Rush River, and 3.4 miles of the Lower Rush River, between the diversion channel and their respective confluences with the Sheyenne River. Figure 91 shows the potential impact areas for the Rush and Lower Rush rivers for the North Dakota diversion alignment. This river habitat would be directly lost as a result of the project. However, these sections of both tributaries are channelized and likely of limited habitat value. Conversely, the North Dakota alternatives would create several miles of flowing habitat in the base of the diversion channel. This habitat would be more abundant, and potentially of better quality, than the habitat lost from abandonment. For these reasons, no mitigation is currently planned for this impact. However, as identified in Section 5.5 Mitigation and Adaptive Management, habitat quality will be further evaluated both pre-project and post-project within these areas. This will help verify, in the future, if effects on the Rush River and Lower Rush River were minimal.

The abandoned channels would likely be identified as areas not to be developed in the future. These areas would thus remain as green space, and likely as functional wetland habitat. The area would probably remain wet in the future due to tiling, drainage and stormflow runoff.

Figure 91 – Potential impact areas for the Rush and Lower Rush rivers

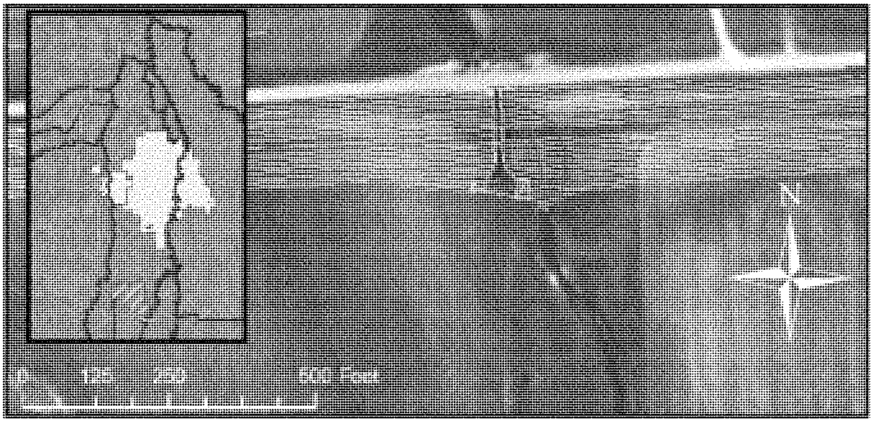


5.2.1.7.1.5 Wolverton Creek Footprint Impact

For both of the North Dakota alternatives, a tie back levee is needed in Minnesota that would cross Wolverton Creek. To accomplish this, a box culvert would be constructed through the proposed levee (Figure 92). The culvert would be located at the same location as an existing box culvert. At a minimum, the proposed culvert would be designed to provide similar hydraulic conditions as the existing culvert. The new culvert and any channel realignment would affect approximately 100 yards of Wolverton Creek. This would impact approximately 0.3 acres of aquatic habitat. Mitigation would be implemented to offset this impact.

Construction activities would result in temporary avoidance of the study area by fish. However, this should be temporary, and would not be expected to have any meaningful long-term effect on Wolverton Creek fisheries. Immobile biota (e.g., invertebrates) would be lost during channel abandonment or placement of rock or other materials.

Figure 92 - Potential footprint area on Wolverton Creek. Channel area impacted outlined in red



5.2.1.7.2 Effects on Red River Floodplain Access Within the Study Area
Many fish species use floodplain areas during flood events. These uses can include spawning, feeding, shelter from high velocities and other functions. All alternatives would reduce flood elevations within the protected area for events that are above 9,600 cfs. This would be observed on the Red River from the control structure, downstream to the confluence of the Red River with the diversion channel.

Flood elevations, and the quantity of area inundated by the river during floods, will change under all alternatives. This would reduce the availability of floodplain habitat for fish use within the study area. The loss in floodplain availability would be relatively small for more frequent events above 9,600 cfs. Losses would differ between alternatives. For example, with the FCP, there could be a loss of about 10-15 percent of the inundated floodplain for frequent flood events (e.g., 5-10 year floods), relative to existing conditions. Conversely, for the LPP and ND35K plan, there could be a loss of about 50-percent of the inundated floodplain for similar events, relative to existing conditions.

Under existing conditions, access to the floodplain in the study area, and its overall value, may be somewhat limited during floods. The area is urban in nature, and the cities of Fargo and Moorhead implement emergency flood protection. With one of the diversion channel alternatives in place, floodplain access for events up to 9,600 cfs event would still occur with the same frequency and flood elevation. Only more extreme and less frequent events would affect floodplain access. During larger floods, biota within the protected area would be subjected to conditions similar to a 9,600 cfs event, and would still have access to floodplain areas inundated at that event.

Under the FCP and ND35K alternatives, floodplain access would remain unchanged upstream and downstream of the protected area, providing large areas of habitat during flooding. Under the LPP, floodplain access would actually increase substantially upstream of the protected area. Also, no scientific evidence has been found that suggests floodplain access is a limiting factor for fish populations or communities in the Red River basin. Any localized effect to the fish community due to reduced floodplain access in the study area would most likely be undetectable in terms of a population or community response. Thus, the changes in floodplain habitat access would be expected to have a less-than-significant impact to the fish community of the Red River and adjacent tributaries.

5.2.1.7.3 Fish Stranding within the Diversion Channel
All alternatives include a diversion channel that will convey significant flow during flood events above 9,600 cfs at Fargo. For the FCP, the diversion channel would be approximately 25 miles long, compared to approximately 36 miles long for the LPP and ND35K.

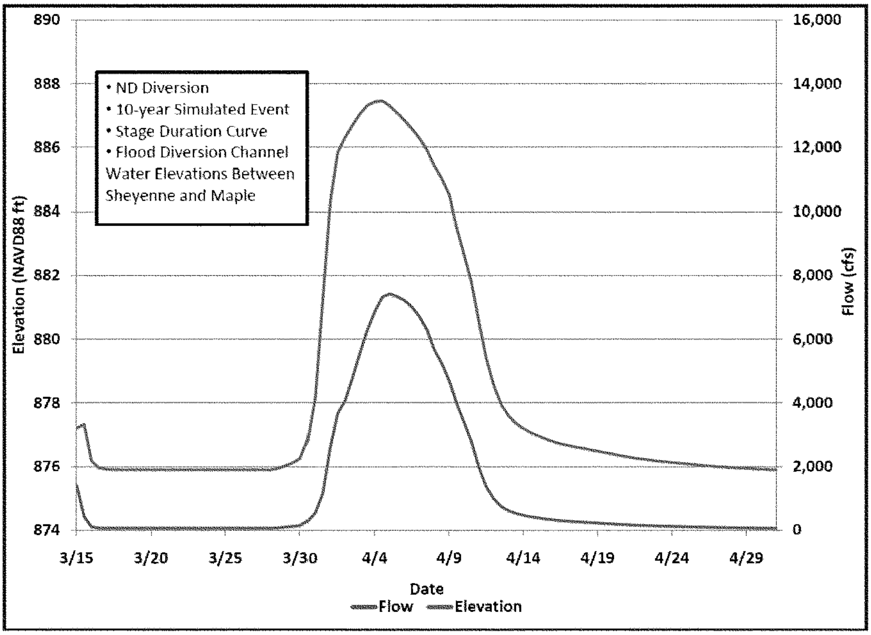
With any alternative, the diversion channel could be used by fish during flood periods when fish may be drawn into the channel. Fish use of the channel would not be considered a benefit. During periods when the diversion channel is not in operation, there may be a small amount of water present at the bottom of the diversion due to ditches and drainage tiles discharging to the upper end of the diversion channel. However, this is not expected to provide any meaningful fisheries habitat. For the North Dakota alternatives, the downstream end of the diversion channel could be used continuously by fish as this area will include a low-flow channel. This low-flow channel will be built to permanently convey flow from the Rush and Lower Rush Rivers and will have year-round flow.

Concern has been expressed that fish stranding could be an issue under any alternative. As waters recede toward the end of a flood, fish in the diversion channel could become trapped if water levels fall too quickly. This could result in fish mortality from isolation and stranding, poor water quality and predation.

To aid in assessing the potential for fish stranding, the Corps performed modeling of stage hydrographs at locations within the diversion channel for the LPP. The location represented in Figure 93 is situated between the Sheyenne River and Maple River crossings. The modeling process including the development of the 10-percent chance event hydrograph are described in Appendix B. The 10-percent chance event was selected as it would be most representative of more frequent flood events where the project would operate. Modeled results and the impact conclusions for fish stranding would generally be the same amongst the LPP, FCP and ND35K alternatives.

Review of modeling output for the simulated 10-percent chance event suggests that water elevations within the diversion channel would decline at different rates along the descending hydrograph (Figure 93). The decline in water surface elevations could be up to about 2.5 ft per day. This rate of decline would decrease toward the end of the flood. As water depths become shallower in the diversion, water elevations would decrease at rates up to about a foot per day or less.

Figure 93 - Water surface elevations within the LPP diversion channel for a simulated 10-percent chance event hydrograph.



As water levels decrease, fish would be expected to respond by migrating downstream out of the diversion channel. The flow control structures for the diversion channel would be designed to have a low-flow notch to avoid an instant cut-off of flow once river elevations drop to the elevation of the control weir. In addition to the meandering channel in the downstream end of the diversion channel for the North Dakota alternatives, a low-flow channel would be created at the base of the diversion channel under any diversion channel alternative. This low-flow channel would run the entire length of the diversion channel, and is necessary to account for the water that is expected to flow through the diversion channel under most conditions. This water would originate from field and tile drains and flow into the diversion channel. The low flow channel would be three feet deep, with a bottom width of 10 feet and a top width of 34 feet. This low flow channel and additional discharge would help remaining fish exit the diversion channel. While it is possible that a few larger fish could be lost in isolated pools within the diversion channel, it is believed that this would not be a significant issue during project operations. No significant impacts to long-term fish populations trends would be anticipated from fish stranding within the diversion channel under any diversion channel alternative.

5.2.1.7.4 Effects of Fish Stranding in the Floodplain

Fish naturally use river floodplain areas during periods of high water. Under natural conditions some fish become trapped and are lost when water elevations drop. Under the LPP, water will be staged upstream to minimize downstream impacts to flood elevations. This staging will flood large areas of floodplain that will be accessible to fish. If water elevations subsequently drop too quickly on the descending limb of the hydrograph, fish could be trapped or stranded, resulting in mortality. Although such conditions occur naturally, concern exists that the hydraulic conditions created under the LPP could be so extreme that fish mortality due to stranding could become too frequent or drastic to where fish populations could be effected. This condition would not occur under the FCP or ND35K. Impacts discussed below are specific to the LPP.

Conditions that could most likely affect long-term fish population trends under the LPP are flood events that occur frequently. Under the LPP, the project could be operated with staging for flood events with a discharge as low as 9,600 cfs. Such flood events have occurred 23 times since 1943, and 15 times in the last 22 years.

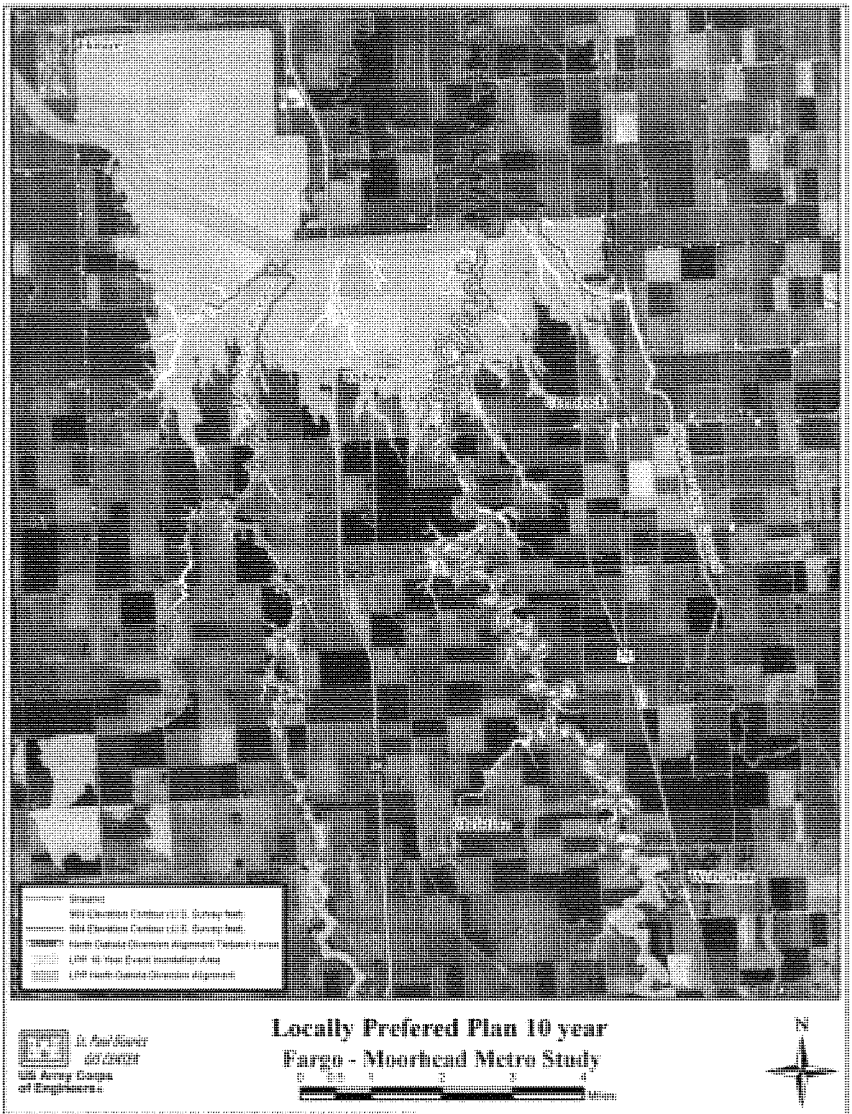
To assess potential impacts, the hydraulic modeling output was analyzed for the simulated 10-percent chance event (17,000 cfs at Fargo). This was the most frequent flood modeled and can provide insight into stranding potential. Under the LPP, approximately 20,841 acres of land would be inundated, compared to 7,858 acres under existing conditions (Figure 95). This includes large areas of land that is a considerable distance from the Red and Wild Rice rivers. During recent floods, river stage as measured at the USGS gage in Fargo has shown drops in water levels between 1.0 and 1.5 feet per day under existing conditions. By comparison, review of the modeling output for a 10-percent chance event for the Red River immediately upstream of the proposed control structure showed a range in water elevation declines. Drops in water elevations initially range from 0.2 to 0.6 feet per day, increase to a maximum rate of 3.6 feet per day, before decreasing to 0.3 to 0.5 feet per day.

Drops as rapid as 3.6 feet per day are considerably faster than natural conditions and could be especially problematic for fish on a floodplain as flat as the Red River. However, a more detailed review of the modeling output provides additional context on the significance. The initial drops in water elevation were associated with water that was spread out across the floodplain. By the time water elevations began dropping by 2.0 feet per day or more, upstream water elevations had dropped to an elevation of 909. The area inundated at this point was fairly confined to the Red and Wild Rice rivers (Figure 94). Water elevations that were dropping at the maximum rate (3.6 feet per day) occurred when water elevations were at approximately 904. This elevation is associated with river levels that appear within existing channels (Figure 95).

The precise operations of the project under the LPP will require extensive analysis prior to implementation, and almost certain refinement over time. It is uncertain how closely the current modeling for the 10-percent chance event represents future project operations. It also should be recognized that river discharge could be quite different than what is portrayed in the model. That said, review of the model data suggests that water elevations will drop more gradually (e.g., 0.2 to 0.6 feet per day) when fish may be most susceptible to stranding. This could suggest the stranding potential is lower, which could translate to conditions that might not substantially impact fish populations. However, the true impact is very hard to predict, especially given exact operations have yet to be determined, and the project could stage water for even very frequent flood events (e.g, flows of 9,600 cfs at Fargo). At this time, the likely impact to long-term fish population trends remains largely unknown. It should be realized that even with optimal operations, some individual fish may become stranded following project operations that involve substantial staging of water. This loss by itself would not necessarily constitute a significant impact.

The risk to fish stranding will require additional consideration during development of the project operating plan. It also will include observation during the first few flood events to verify resulting stranding. If substantial stranding is identified, the best option likely is to modify project operations, if possible, to reduce stranding potential. Other options could include construction or grading activities within known problem areas to minimize potential for stranding. Any action to avoid, minimize or mitigate such an impact would be considered collectively amongst the non-federal sponsors and natural resource agencies. No specific mitigation is planned at this time for this issue. This issue can be revisited by the non-federal sponsors and agencies as warranted in the future.

Figure 94 - Area of upstream staging for the LPP during the modeled 10-percent chance event. Map indicates floodplain elevation 909 and 904 ft msl relative to flooded area.



5.2.1.7.5 Effects on Fish Passage and Biotic Connectivity for Red River
Under any diversion channel alternative, fish passage on the Red River could be impacted by the Red River control structure and diversion channel. Flow velocities and patterns would be modified with the Red River control structure, which could in turn influence the ability for fish to migrate. The diversion channel could affect how fish migrate upstream through the Red River during flood events given the diversion will convey a large percentage of total-river flow. In addition to fish, the diversion channel alternatives could also affect organisms such as freshwater mussels that rely on fish as a host species during portions of their lifecycle. Impacts are discussed below for both the control structure and the diversion channel. Impacts for the Red River and diversion channel would generally be similar amongst alternatives.

5.2.1.7.5.1 Red River Control Structure Effects on Connectivity
Flow velocities through the control structure must remain low enough that fish can successfully migrate upstream. This is especially important during months when fish tend to migrate, though the ability for free fish movement can be important during all months of the year. It is also important to provide a variety of flow velocities and patterns, as opposed to providing uniform flow. Under natural conditions, rivers typically have a range of flow velocities within the channel, providing lower-velocity zones fish can use to successfully migrate upstream.

A complete description of the proposed Red River control structure is provided in Section 3.7 (also see Figure 95 and Figure 96). A complete discussion of hydraulic modeling and analyses for the diversion channel alternatives is included in Appendix B, Hydraulics. The location of the control structure will vary between the North Dakota and Minnesota alignments, namely its location above or below the Wild Rice River. This could result in slightly different designs and hydraulic conditions between the North Dakota and Minnesota alternatives. However, for this analysis, it is assumed the Red River control structure would be designed to provide similar hydraulics regardless of diversion alignment. The designs used here for the different alignments generally result in similar flow velocities and patterns through the structure.

Under most conditions, the proposed control structure on the Red River will essentially function as a bridge with flows passing below without constriction. The structure under any diversion channel alternative includes three gates that are 50 ft wide. Each gate bay sill will be approximately 90 ft long, meaning fish would have a 90-ft span to migrate through the structure. A combination of rocks, and possibly concrete baffle blocks, placed in the concrete bottom sill of the control structure will provide roughness and flow complexity along the bottom of the channel. This will provide fish a variety of velocities and flow patterns with which they can migrate upstream, provided velocities remain suitable. Water depth through the structure would not be a concern, as even under low summer flows water depths through the structure would be on the order of several feet.

Figure 95 - Schematic of proposed Red River Control Structure without flow.

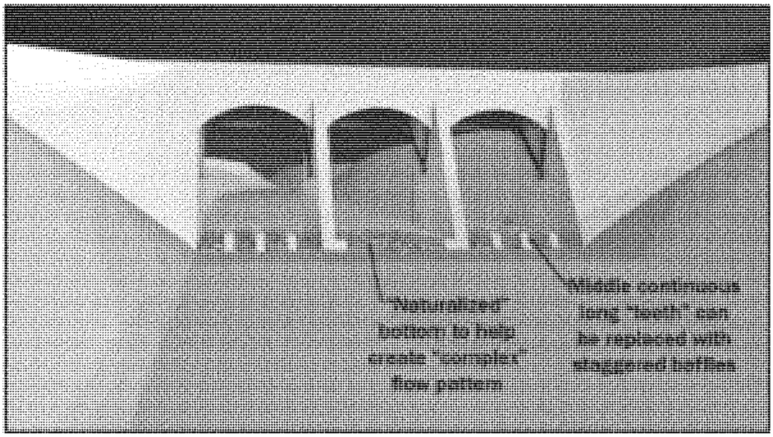
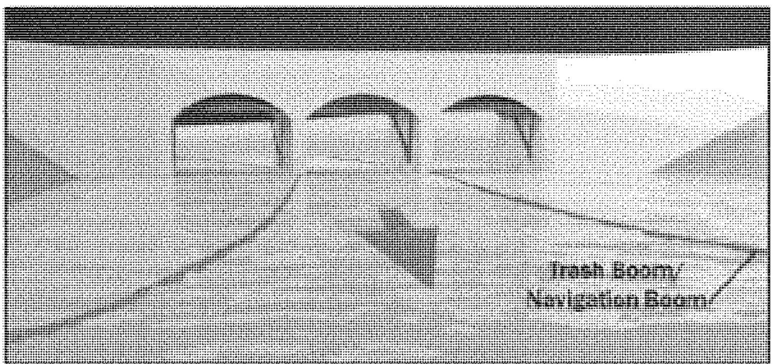


Figure 96 - Schematic of proposed Red River Control Structure with flow. Gates are out of the water, and the project is not in operation.



Under existing conditions, average flow velocities at Fargo are well under 1 foot per second (ft/s) for the annual median flow of 360 cfs, and usually average 1-2 ft/s for flows around 3,500 cfs. Velocities increase to an average of 1.5 to 4 ft/s for flows around 9,600 cfs (discharge at Fargo where the project would begin operating), and can increase more for larger events (Figure 97 and Figure 98). Velocities observed across a transect at Fargo, ND during flood events include areas of higher velocity mid-channel (e.g., flows greater than 3 ft/s). However, lower velocity areas (e.g., 1-2 ft/s) also occur near the channel perimeter, and up onto the floodplain (Figure 97 and Figure 98).

Figure 97 - Observed average channel velocities for the Red River at Fargo, North Dakota, USGS gauge 05054000, for various river discharges. Source: USGS.

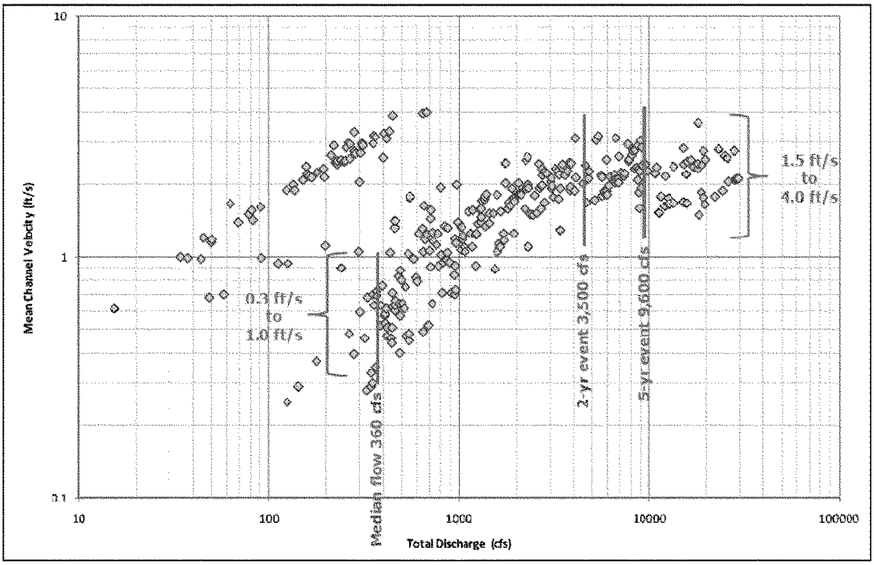
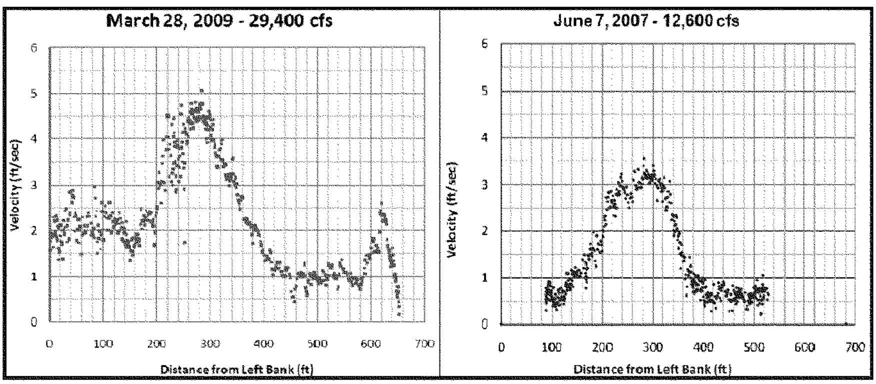


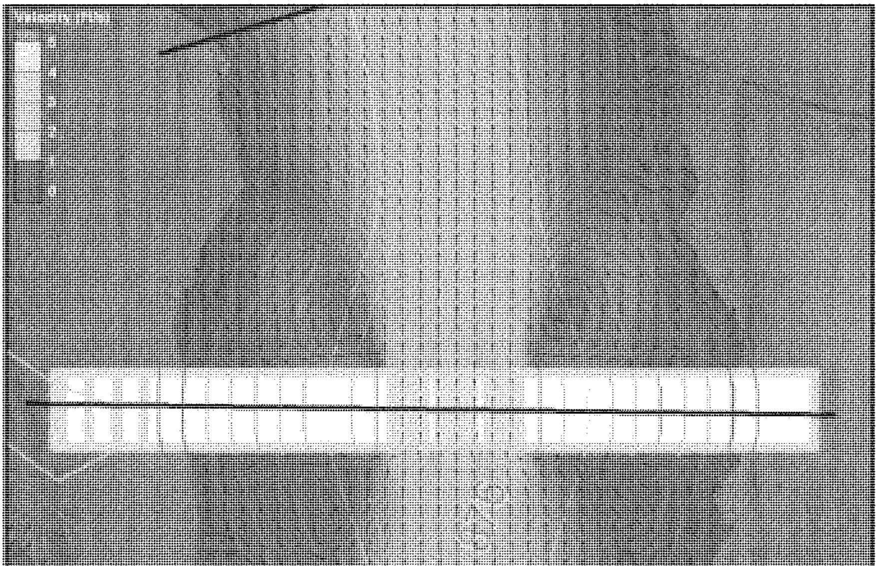
Figure 98 - Observed average channel velocities across a channel transect for the Red River at Fargo, North Dakota, USGS gauge 05054000, for a river discharges of 12,600 and 29,400 cfs. Source: USGS.



Modeling for the LPP was done at discharge levels similar to those immediately prior to the control structure going into operation. At those discharge levels, all flow is directed through the control structure and represents a "worst case" scenario in terms of velocities when the project is not in operation. Modeled velocities at this discharge suggest an average approximate flow velocity of 1.5 ft/s through the control structure. This approximate velocity would occur for the LPP and ND35K. Modeling of the FCP under similar flow conditions observed velocities of approximately 2.0 ft/s through the control structure. Modeling for lower discharges would see lower corresponding velocities.

The average velocities noted in the preceding paragraph, in combination with rock and concrete placed in the bottom of the channel to increase flow diversity, should ensure the proposed structure under any alternative is functional for fish passage, similar to existing conditions, for river discharges up to the event where the project would go into operation (e.g., approximately 9,600 cfs at Fargo), Figure 99.

Figure 99 - Depth-averaged velocity for Red River Control Structure under the LPP for the discharge just before which the project would go into operation (i.e., generally equivalent to 9,600 cfs at Fargo, ND). Modeling assumes increased roughness along river bottom via baffle blocks or rock boulders. Velocity profiles would be similar for ND35K.



When the proposed Red River control structure is placed into operation, the gates would be lowered to begin controlling flow. This would result in constricted flows through the structure, with a substantial increase in current velocities. Although this exact situation has not been modeled, it is likely that velocities through the gate bays would be 8 to 10 ft/second, if not substantially more, for all of the diversion channel alternatives. The velocities would be well above existing conditions, and above what can be reasonably assumed to be passable for all fish species on the Red River. As such, it can be assumed that fish would not be able to pass through the proposed Red River control structure when it is in operation.

To minimize impacts to fish migration during periods when the project is in operation, fish passage channels would be incorporated into the control structure. The tentative, preliminary plans of the fish passage channels are described below. These are basic designs made for the purpose of cost-estimation, and more refined designs will be needed in the next phase of planning. This will include collaboration with State and local biologists, and other fish passage experts as necessary, to design an effective structure. The fish passage channels will be designed to maximize the opportunity for fish passage, to the extent practical, during high-flow events. The channels would provide an avenue for fish passage beginning at approximately the time the project goes into operation. The channels would operate until water elevations approach levels approximately corresponding to 20,000 cfs under the LPP; and between 29,000 and 30,000 cfs under the FCP and ND35K. At this point, no fish passage would be possible as the fish passage gates would be closed to protect the control structure from extreme hydraulic conditions. It should be noted that the limit of operation of the fish passage gates is dictated by upstream water elevations, and these elevations could vary under the LPP for a discharge of 20,000 cfs depending on how water must be staged to account for the peak flow discharge and timing.

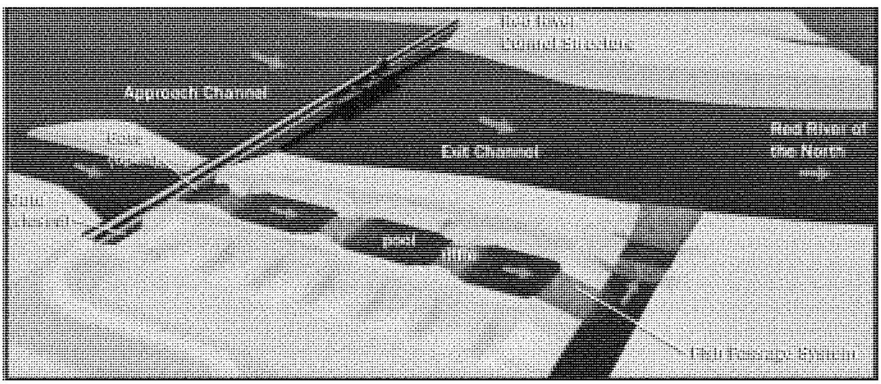
The current, preliminary fish passage system includes two channels with gates to facilitate flow through the Red River control structure (Figure 100). Each channel would be operated individually (i.e., channels would not operate simultaneously). The preliminary plans include channels with a general grade of about 2.2-percent and average velocities between 2 to 6 ft/sec through the control gate. The fish passage channels are tentatively planned to include pools that are 40 ft wide, with a total channel length up to 900 ft. However, the length may change as channel design is optimized for effectiveness and cost. Depending on design and any upstream staging, total discharge conveyed through any fish passage channel would be between approximately 50 and 600 cfs. This would be up to approximately 6 percent of the total flow through the Red River control structure. The fish passage channels will include a downstream entrance as close as possible to the Red River control structure to maximize the potential for fish to find and use the fish passage channel. The upstream exit of the channels would be placed off to the side of the Red River control structure to ensure that fish do not get drawn back into the control structure at high velocities.

Current project designs for all diversion channel alternatives include two fish passage channels to facilitate fish passage during periods when the project is in operation. Two channels would work for a wide range of flows under the FCP and ND35K alternatives. However, two channels would provide limited connectivity during floods with the LPP in place. Under the LPP, water must be staged upstream to account for downstream water level increases. As such, upstream water elevations fluctuate much more substantially under the LPP. Gates through the structure that allow for fish passage are designed for a height of 5 ft, and can only operate with water depths through the gate between 1 ft and 4.5 ft. However, for a flood with a peak flow of 17,000 cfs at Fargo (10-percent chance event), water elevations could fluctuate 23 to 24 ft from the time the project goes into operation up to peak river discharge. If only two gates were utilized it would result in narrow periods during the hydrograph where fish passage could be provided. Six additional channels would be necessary (eight fish passage channels total) to provide fish passage across a range most flow conditions. The additional gates also would provide fish passage up to an approximate discharge of 30,000 cfs. As discussed in 5.5.2 (Mitigation), six additional fish passage channels (eight total) will be included as mitigation for the LPP to provide for fish passage up to approximately 30,000 cfs. As additional information is gathered during the design and implementation phase, the mitigation may be optimized with a combination of equally effective measures.

To further improve the potential success of the fish passage channels under the LPP, several options will be considered. This could include installation of additional gates to provide additional fish passage channels that would function across more of the hydrograph. It also could include methods to reduce the amount of staging needed, or the duration of time staging is needed, for the LPP. It also could include options to pass additional water through the metro area, above 9,600 cfs at Fargo. This would allow the project to operate less frequently, and potentially require staging less water, which could help mitigate the impact on fish.

It is recognized that a fish passage channel is not as effective for fish passage as an open, un-constricted channel with natural flows. However, with careful design, the fish passage channels should provide another route for fish to migrate upstream past the control structure. As discussed in Section 5.5 Mitigation and Adaptive Management, fish passage through the control structure (including the fish passage channel) will be further evaluated to verify effectiveness. This would include post-project monitoring to gauge the effectiveness of these structures in facilitating fish migration.

Figure 100 - Tentative design of the fish passage channels for the Red River control structure. Two channels would provide fish passage under most flow conditions between 9,600 cfs and approximately 29,000 and 30,000 cfs under the FCP and ND35K. Up to eight channels would provide fish passage under most flow conditions for a similar discharge range under the LPP.

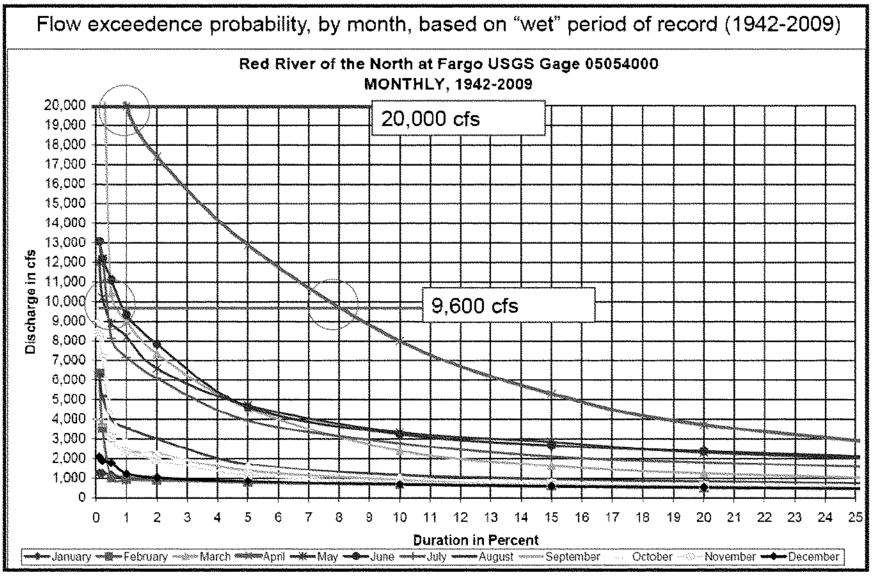


Overall, Red River fish passage most likely would not be impacted under most flow conditions. However, some limitations would exist. Under all diversion channel alternatives (including the LPP with additional mitigation measures), a fish's ability for migration could be reduced, relative to existing conditions, for river flows between 9,600 cfs and approximately 29,000 to 30,000 cfs at Fargo (period when fish passage channels would operate). Fish passage would be halted completely under all diversion channel alternatives for flows above approximately 29,000 to 30,000 cfs. To better understand the context of these impacts requires understanding the timing and frequency of when these limitations would occur.

Discharge frequency was analyzed for available USGS gage data collected at Fargo, North Dakota. Historical daily flow data exists for this gage site dating back to 1901 (108-year period of record). However, hydrologic conditions in the early 20th century are very different from conditions in the later part of this period. Thus, the entire period of record may not be a good indicator of flow frequencies. A statistical analysis was performed to assess a period of record that may better approximate more recent flow regimes (see Appendix A). From this effort, the period 1942 through 2009 was identified as the period of record (Appendix A). This period better represents more recent conditions (e.g., more "wet" conditions), thus providing a more realistic representation of given flow frequencies.

When considering the period 1942 through 2009, Red River flows at Fargo, ND are at or below 9,600 cfs at Fargo, ND over 99-percent of the time annually. When considering flow data on a monthly basis for the wet period (1942-2009), flows exceed 9,600 cfs 1-percent or less of the time during all months except April (Figure 101). During the month of April, flows exceed 9,600 cfs about 8-percent of the time (an average of about two to three days), and exceed 20,000 cfs at Fargo, ND 1-percent or less of the time during all months (Figure 101).

Figure 101 - Percent of the time various flows are exceeded, by month, for the USGS flow gauge at Fargo, ND (USGS Gage 05054000) for the period 1942 through 2009. Comparison is made among the percent of the time flows exceed 9,600 cfs and 20,000 cfs at Fargo, ND.



Daily discharge data, for the period 1901 through June 2011 (this includes preliminary data from 2011), was further reviewed for the Red River USGS gauge at Fargo to understand potential impacts. Under all three alternatives, upstream fish migration would not occur above approximately 29,000 to 30,000 cfs. However, such conditions have never occurred since 1901. The fish passage channels will be designed to operate up to levels observed during the 2009 flood in Fargo. While a flood will occur at some point in the future greater than 30,000 cfs, it is reasonable to conclude that such conditions would happen extremely infrequently.

Under all diversion channel alternatives upstream fish migration could be more limited between approximately a 9,600 cfs and 30,000 cfs. Since 1942 there have been 23 events where discharge exceeded 9,600 cfs at Fargo, ND (including 2011). These events averaged about 10.7 days where flows were above 9,600 cfs. Five events (1997, 2001, 2009, 2010 and 2011) had conditions where flows were above 9,600 cfs for at least two weeks.

Impacts to connectivity under the LPP would be more pronounced. Because this alternative stages water, there is a protracted period when the project would operate. For a 10-percent chance event (17,000 cfs at Fargo), modeling suggests the project would potentially operate for a period of 19 days. Similar flood events at Fargo where floods peaked around 17,000 cfs (e.g., 1978, 1979 and 1989) might have resulted in the project operating for 7 to 10 days under the

FCP or ND35K alternatives. This may suggest that under the LPP the project might operate about twice as long as it would under the FCP or ND35K for a 10-percent chance event. These impacts will be further refined as the projects operating plan is developed in greater detail.

The timing of seasonal fish migrations is outlined in Section 4, including observations for specific species. Fish migrating upstream during the month of April would have the greatest likelihood of being restricted by the diversion channel alternatives. The majority of flood events where the project would have operated historically occurred in April, though similar floods have occurred in the months of March through July. April is important for connectivity, particularly later in the month, as supported by observations of fish migration in the basin. A wide range of species could potentially experience limited capability for migration during certain conditions under any of the diversion channel alternatives. Two species of specific concern on the Red River, lake sturgeon and channel catfish, generally migrate later in the spring (e.g., May through July). While migrations of these species could be affected, they typically appear to migrate later in the spring when the project is less likely to operate. Project operations could occur more frequently in May under the LPP, compared to the FCP and ND35K, due to the need to stage water upstream.

Although connectivity could be reduced, fish passage would still be possible under most conditions via the fish passage channels. Under the FCP and ND35K, the amount of time the project would operate is low. Under the FCP and ND35K, the project would historically have operated only 8 percent of the time in April (an average of two to three days), and less than 1 percent of the time in all other months. Effects would be more pronounced under the LPP, where the project could operate twice as long for more frequent flood events. Though variable by species and yearly conditions, fish migrations and spawning activities often occur over a period of a few weeks or more. Thus, under the FCP and ND35K, fish passage would be affected for a short duration, and not substantially affect an entire migrational period for a given population. Fish passage could be affected under the LPP for comparatively longer, and could occur over a broader period that might encompass the bulk of a spring migratory movement for some species.

In conclusion, the FCP and ND35K would largely avoid and minimize significant adverse impacts to fish migration. As outlined above, the FCP and ND35K would have a small adverse effect on biotic connectivity. However, although connectivity would be slightly affected, it appears unlikely this effect would result in a detectable response as might be observed by a change in long-term fish population trends. Thus, the FCP and ND35K would likely have a less-than-significant impact to fish population levels in the Red River basin as a result of slightly reduced connectivity.

The LPP, with its longer operational period, could have a more significant impact to Red River connectivity. Still, with the inclusion of eight fish passage channels, or an optimized combination of equally effective measures, it would appear unlikely that the LPP would restrict connectivity to an extent that fish populations might have a measurable impact. However, given the potential risk, given some of the remaining uncertainties on exactly how project features will be operated and their effectiveness, and given the concern expressed by natural resource agencies during the collaboration for this project, it is concluded that the LPP could have a potentially significant impact to fish populations within the basin. As such, additional mitigation would be implemented under the LPP to address this potential impact (see Section 5.5 and Attachment 6).

5.2.1.7.5.2 Wild Rice River Connectivity
Fish passage on the Wild Rice River would be impacted by the Wild Rice control structure and proposed diversion channel under the LPP and ND35K. Flow velocities and patterns would be modified with implementation of the flow control structure, which could in turn influence the ability for fish to migrate upstream and downstream. No such effects would occur under the FCP.

A complete description of the Wild Rice River control structure, including operation, is provided in section 3.7. Impacts to connectivity on the Wild Rice would be very similar to those discussed for the Red River control structure. Under most conditions, the control structure on the Wild Rice River would essentially function as a bridge with flows passing below without constriction. The structure, as designed for this study, includes two gates that are 30 ft wide. A combination of rocks, and possibly concrete baffle blocks, placed in the river bottom at the control structure will provide flow complexity along the bottom of the channel. This will provide fish a variety of velocities and flow patterns with which they can migrate upstream, provided velocities remain suitable. Water depth through the structure generally would not be a concern, as even under low summer flows, water depths through the structure would be about 2 feet deep. This is similar to existing channel cross sections.

A complete discussion of hydraulic modeling and analyses for the project is provided at Appendix B. Hydraulic modeling of the North Dakota alternatives predicted average flow velocities of 2.5-2.7 ft/s through the control structure under conditions just prior to the project going into operation. These average velocities, in combination with rock and concrete placed in the bottom of the channel to increase flow complexity, should ensure the proposed structure is functional for fish passage, similar to existing conditions, for river discharges when the project is out of operation.

The Wild Rice River control structure would be placed into operation in concert with the Red River control structure, meaning the gates would be operated with the same frequency as those on the Red. When the gates are in the water, the constricted flows would result in substantial current velocities that would preclude fish movement. Since the two structures would be operated in concert, the frequency and duration of operations discussed for the Red River control structure also apply to the Wild Rice structure. The limitations for connectivity on the Wild Rice are thus highly similar to those described for the Red River under the LPP and ND35K.

To minimize impacts to fish migration when the project is operating, two fish passage channels would be constructed at the Wild Rice control structure. The preliminary plans of the fish passage channels are similar to those described for the Red River, with the preliminary designs included at Attachment 5. In addition, the operational capabilities for these fish passage channels are highly similar to those outlined for the Red River structure. With careful design, this fish passage channels should provide another route for fish to migrate upstream past the Wild Rice River control structure.

It is likely that the ND35K alternative would largely avoid and minimize significant adverse impacts to fish migration on the Wild Rice River. Any remaining adverse effects to fish connectivity would likely be very small and undetectable in terms of measurable population changes or response by fish populations.

However, effects on connectivity would be more pronounced under the LPP, where the project could operate twice as long for more frequent flood events. In addition, the current design for fish passage at the Wild Rice structure only includes two channels. While this would facilitate fish passage for most river conditions under the ND35K, it would leave gaps in the hydrograph under the LPP when fish passage would not be possible. Though variable by species and yearly conditions, fish migrations and spawning activities often occur over a period of a few weeks or more. Conditions under the LPP would be comparatively longer, and could occur over a broader period that might encompass the bulk of a spring migratory movement for some species. Given this, the LPP could have a potentially significant impact to connectivity on the Wild Rice, particularly without additional gates to facilitate fish passage. To address this issue, mitigation is recommended in Section 5.5 to offset connectivity impacts on the Wild Rice.

5.2.1.7.5.3 Maple and Sheyenne River Connectivity

Fish passage and aquatic habitat connectivity on the Maple and Sheyenne rivers could be impacted by the LPP and ND35K, due to the aqueducts that pass stream flows over the diversion channel. The structures would be concrete channels with similar widths to the natural channel. The concrete structures would be about 650 ft long from upstream to downstream. Water depths through the structure would remain similar to existing conditions. Likewise, water velocities passing through the aqueducts would remain within the general range of what occurs under existing conditions. Water velocities would generally be less than 2 ft/s for discharges up to a 50-percent chance event flow, with lower velocities for lower discharges (Figure 102 and Figure 103). Both aqueducts would include boulders or other hard-points strategically placed to provide flow complexity to aid in fish migration. Both aqueducts also will include a low-flow channel at its base, ensuring water depths to help migration even under low flows.

The tributary flow structures would reduce flood flows on the Sheyenne and Maple rivers. Flood flows up to at least a 50-percent chance event would pass through these structures. Above that, additional flows would be diverted into the diversion channel. As such, flows through the structures would not exceed those levels identified for a 50-percent chance event. Given this, and the potential velocities through the structure, it appears fish migration through the structure generally would not be substantially affected.

The diversion channel could affect how fish migrate upstream through the Red River during flood events given the channel will convey a large percentage of total-river flow. It could also affect the number of fish that migrate up tributary streams. The proposed structures on the Sheyenne and Maple rivers would have overflow channels that divert excess tributary flows into the diversion channel. These overflow channels will include rock as grade control. If practicable, these structures will be designed to be passable to fish which would allow fish to migrate from the diversion channel into the Maple and Sheyenne rivers. However, if a cost-effective design cannot be developed, then fish that pass upstream into the diversion channel would not have access to the Maple and Sheyenne rivers.

Although the proposed system would result in altered hydraulics and an unnatural condition, both the Sheyenne River and Maple River would remain biologically connected at all times. Existing conditions include limited connectivity as a result of several dams on both the Maple and Sheyenne, including one each downstream of their proposed aqueducts. Ultimately, the North Dakota alternatives would likely not have a significant impact to Sheyenne and Maple river fish communities due to altered connectivity.

Figure 102 - Average velocities for the Sheyenne Aqueduct under the LPP for a discharge equal to a 2-year event.

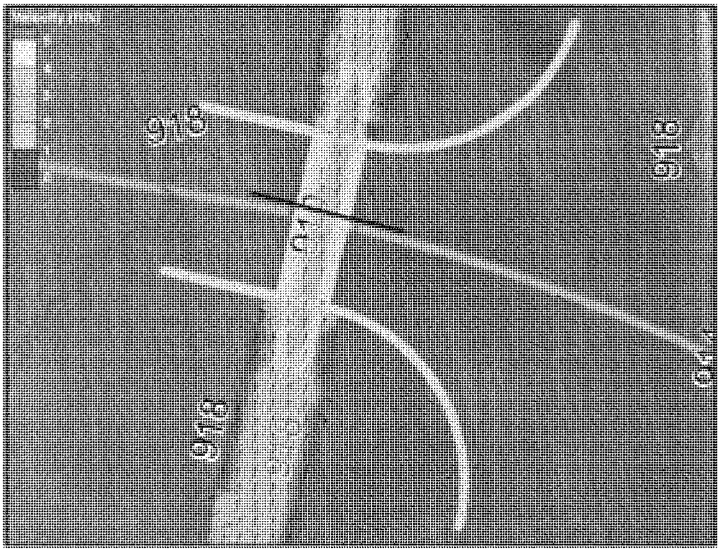
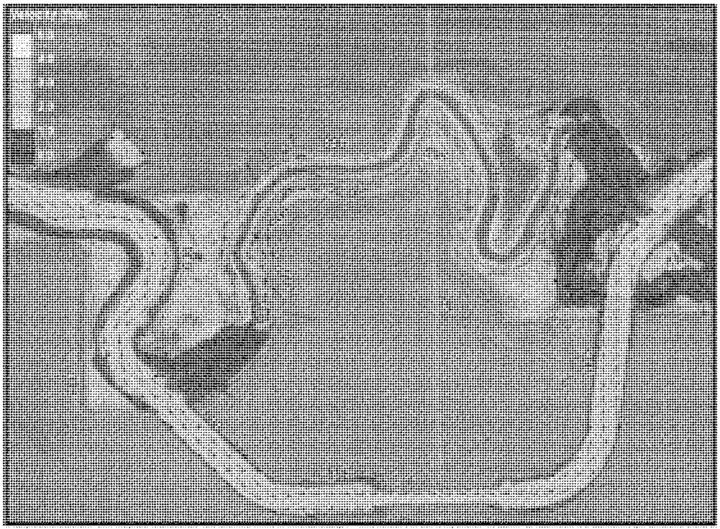


Figure 103 - Average velocities for the Maple Aqueduct under the LPP for a discharge equal to a 2-year event.



5.2.1.7.5.4 Rush and Lower Rush River Connectivity
Fish passage and aquatic habitat connectivity on the Rush and Lower Rush rivers could be impacted by the LPP and ND35K. Weirs would be constructed to step flows from the existing channels, down to the base of the diversion channel. Given the slope and need to convey a range of flow volumes it could be difficult to make these weirs directly passable for fish. Current plans include constructing a fish passage channel for both the Rush and Lower Rush Rivers to facilitate migration. These designs are included in attachment 6. These features should be passable to fish across the majority of flow conditions, with the possible exception of substantial flood events.

The need for fish passage for these two rivers will be studied further in subsequent NEPA documentation as appropriate. Given the apparent upstream habitat available on the Rush River, the need for fish passage appears greater. Conversely, the Lower Rush River is an intermittent river, and may be dry during periods of the year. The concept of fish passage will be evaluated further to determine whether the Lower Rush provides any habitat values for migratory fish. This consideration is important given that accommodating fish passage into each river could cost several million dollars.

5.2.1.7.5.5 Wolverton Creek Connectivity
Fish passage and aquatic habitat connectivity on Wolverton Creek could be reduced under the LPP and ND35K. Under these alternatives, a tie-back levee is needed to extend from the Red River control structure back across the floodplain. This will cross Wolverton Creek and require a box culvert to convey creek flows. The levee and culvert would be built adjacent to an existing road and boxculvert. For this study, the new box culvert was assumed to match the existing culvert.

Under the ND35K, the new culvert for Wolverton Creek should allow fish to pass in a similar manner as with the existing culvert. Additional design work could be done to make this a "fish friendly" culvert, to help facilitate fish movement. Such actions can be done with relatively low cost.

Fish passage through the new Wolverton Creek culvert will be more affected under the LPP. For this alternative, fish would be able to migrate through the culvert when the project is not operating. During operation of the LPP, water will be staged upstream, which could create a substantial head difference on both sides of the culvert. This will require the use of a gate to stop flow through the culvert . This would halt fish movement through the culvert during the period of project operations. The timing and periodicity would be similar to that outlined above for project effects to the Red and Wild Rice rivers. As such, the LPP could potentially affect fish populations and communities within Wolverton Creek. However, it is unclear if this impact is substantial enough to warrant additional mitigation beyond what has already been proposed in the FEIS. Measures will be studied during more detailed project planning to minimize this impact to the extent practicable. At this time, no mitigation specific for Wolverton Creek connectivity has been included. The issue of mitigation would be revisited if project monitoring, or other information, suggests this connectivity impacts warrants additional action. Any future mitigation action for Wolverton Creek would need to be balance mitigation costs with the impact.

5.2.1.7.5.6 Red River Diversion Channel Effects on Connectivity
During operation fish could potentially migrate upstream through the diversion channel. The diversion channel would convey several thousand cfs during major discharge events . The project would not divert water until river discharge is 9,600 cfs at Fargo for the FCP and ND35K. Under the LPP, flows could be diverted at flows below 9,600 cfs, though the amount and duration would vary based on the flood risk. The percent of flow diverted under all alternatives could range from roughly 30-percent to over 65-percent. An example of the potential flow distribution is provided at Table 46. Under the LPP, the distribution of flows between the diversion channel and the protected area varies greatly depending on many factors. The range of water diverted would generally be similar that for the FCP and ND35K.

Table 46 – Potential Flow distribution (in cfs) between diversion channel and Red River below the proposed control structure for the FCP alternative.

Flow conditions differ somewhat under the LPP and ND35K (See Appendix B).

Event	Flow in Diversion Channel	Flow Through Control Structure	Total Red River Discharge	% Flow diverted to bypass
20%	11	9,589	9,600	0%
10%	4,164	10,377	14,500	29%
5%	9,192	9,808	19,000	48%
2%	15,888	9,612	25,500	62%
1%	20,114	9,886	30,000	67%
0.2%	35,049	17,951	53,000	66%

Hydraulic modeling suggests that velocities within the diversion channel could vary based on diversion alignment and alternative (Figure 104 and Figure 105). At a 10-percent chance event, velocities under the FCP would generally be between 1 to 2.0 ft/s (Figure 104). At a 5-percent chance event, the diversion channel would have average velocities between 2 to 2.5 ft/s . The range of diversion channel velocities for the LPP alternative would generally be similar to the FCP, and would range from 1 to 3.5 ft/s (Figure 105) for flood events up to a 2-percent chance event.

Figure 104 - Average velocities for Red River Diversion channel, FCP alternative, during various discharge events. Velocity estimates begin at the confluence of the diversion channel and the Red River, and extend upstream to the diversion weir. Spikes in velocity plots are due to constrictions at bridge crossings.

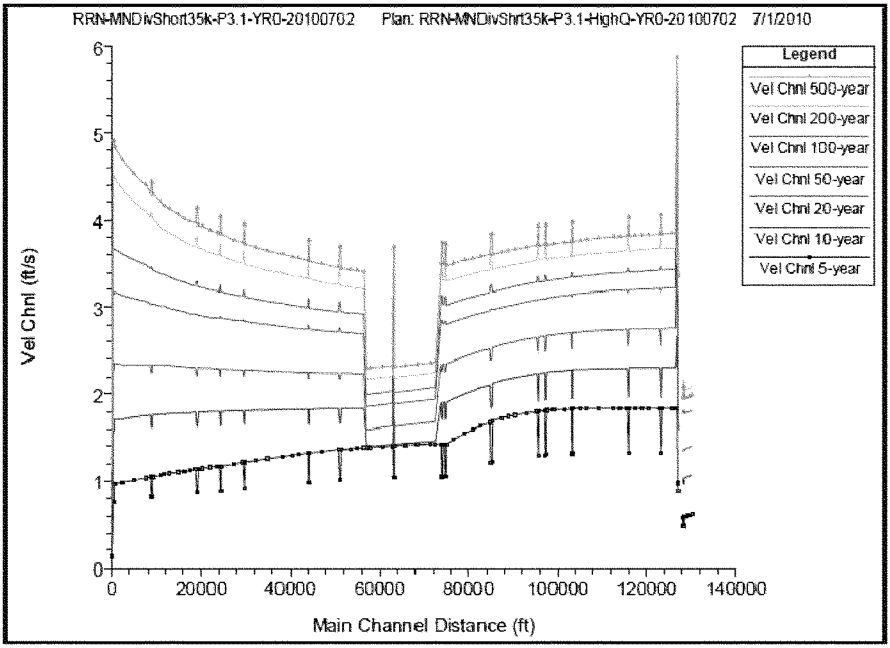
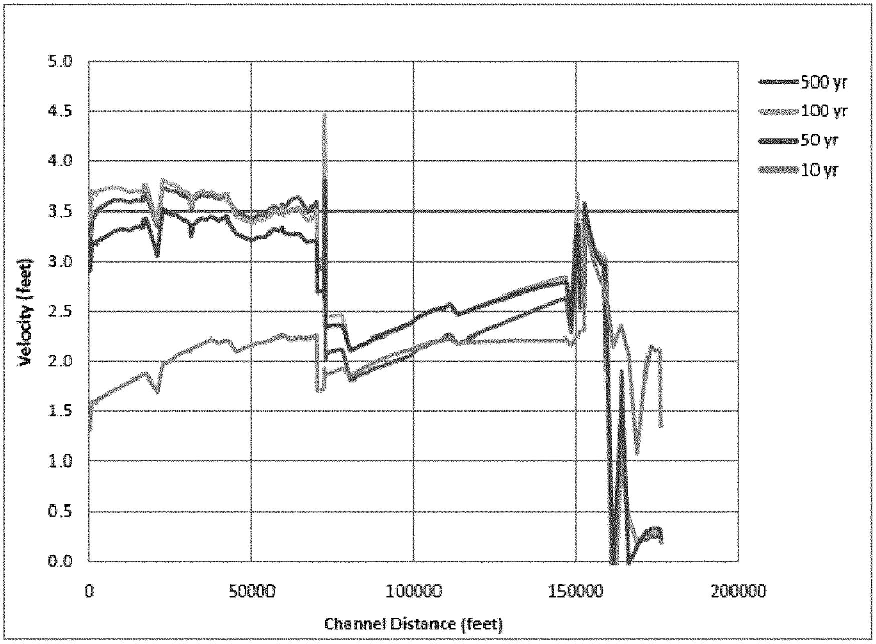


Figure 105 - Average velocities for Red River diversion channel, LPP, during various discharge events. Velocity estimates begin at the confluence of the diversion channel and the Red River, and extend upstream to the Wild Rice River diversion weir control structure. Spikes in velocity plots are due to constrictions at bridge and stream crossings.



The diversion channel would be 25 miles long for the FCP, and 36 miles for the LPP and ND35K. During coordination for this project, Minnesota DNR identified that in their experience, fish movement is substantially impeded within and through long, channelized river segments and ditches. Thus, there remains uncertainty with how many fish might successfully migrate upstream through the diversion channel with the indicated average velocities. However, under any alternative, it is possible the diversion channel would be passable to fish up to about a 5-percent chance event, and possibly even up to a 2-percent chance event.

For the FCP, once at the upstream end of the diversion channel, fish would need to pass over a weir to access back into the Red River. This weir would be designed to accommodate fish passage by building a series of rock rapids at the weir, similar to what has been done at other Red River dams.

For the LPP and ND35K, fish passage at the upstream control weir does not seem feasible. Current designs include a substantial vertical drop from the top of the control weir to the bottom of the diversion channel. Under the LPP, the bypass would be especially problematic due to staging additional water upstream of the control structure. Cursory analysis suggests that including fish passage features for the diversion channel under the LPP could cost at least an additional $10 million. Costs for the ND35K could be less, but still substantial.

Without connectivity on the upper end of the diversion channel for the LPP and ND35K, fish would be required to swim back down the diversion channel to access the Red River. While not ideal, the low-flow channel at the bottom of the diversion should ensure that fish have a route to access back to the Red River when diversion channel flows drop.

Fish migrations could be influenced when the diversion channel is in operation, The frequency and duration of project operations has been outlined above for other impacts. Fish migrating upstream during the month of April would have the greatest likelihood of being influenced by the diversion channel. April is typically a period when fish migrations become more pronounced, with the end of April and early May being especially important for some species.

The tendency that fish would migrate up the diversion channel is unknown. It is possible fish could migrate the entire length of the diversion channel, even during brief periods of operation (e.g., typically a few days). Fish that do access the diversion channel would have the opportunity to migrate back out. The key question is how affected fish migrations might be if they are drawn into the diversion channel, then have to migrate back out to continue to their movements back in the Red River. The effect on migrations, and the subsequent impact to long-term population's trends is difficult to predict. The impact to fish migrations likely can only be evaluated through monitoring once the project has been constructed. If migrational movements are substantially affected, potential mitigation measures might include deterrent systems to keep fish out of the flood diversion. These could be implemented at the downstream diversion confluence, or potentially one of the bridges that would serve as a constriction point.

Since fish would have a path to exit the diversion channel, the risk to direct mortality would be very low. Given this, no mitigation is recommended at this time. However, the potential impact to fish migrations will be evaluated further following project construction. Potential impacts to fish migration will be verified, and the need for any mitigation measures confirmed at that time. Given the uncertainty that this impact would be meaningful, and the apparently high cost with any fish passage feature at the upstream end of the diversion under the LPP or FCP, this adaptive approach is the most appropriate option to address this potential impact.

5.2.1.8 Upland/Riparian Habitat

The surface areas that would have direct impacts for the project features are as follows: FCP, approximately 6,415 acres; ND35K plan, approximately 6,560 acres; and LPP approximately 8,054 acres. Of these areas, disturbance caused by project-related construction would be limited to the diversion channel, spoil disposal area, tie-back levee footprints, storage area levee construction, and construction areas of the river crossing structures. The acreage for the LPP also includes areas used for storage and staging, which would not be disturbed by construction. Forested land in the staging area will be inundated with water while the project operates. Generally the project will only be put into operation during the months of March and April when the trees will still be dormant and the flooding will have no impact on them. Historically there have been times when the project would have operated during the months of May and June, but on these occasions the project would have operated for shorter durations, which also would have a minimal impact on the trees. Floodplain tree species that are in the area have high tolerance to flooding and can withstand an entire growing season inundated with water.

There would be some areas where upland forest and riparian forested areas would be cleared or otherwise impacted. For the FCP the Red River control structure would impact approximately 22 acres of riparian forest; the diversion channel would impact approximately 49 acres of a mix of upland forest and riparian forest; and the Red River outlet structure would impact approximately 18 acres of riparian forest. For the ND35K the Red River control structure would impact approximately 20 acres of riparian forest; the diversion channel and tie-back levees would impact 95.5 acres of a mixture of upland forest and riparian forest; the Wild Rice River control structure would impact approximately 20 acres of riparian forest; the Sheyenne River aquaduct would impact approximately 10 acres of riparian forest; and the Maple River aquaduct would impact approximately 3 acres of riparian forest; and the Red River outlet structure would impact 9 acres of riparian forest. There would be no impacts to forests at the Lower Rush and Rush rivers. For the LPP the Red River control structure would impact approximately 20 acres of riparian forest; the diversion channel and tie-back levees would impact 96 acres of a mixture of upland forest and riparian forest; the Wild Rice River control structure would impact approximately 20 acres of riparian forest; the Sheyenne River aquaduct would impact approximately 10 acres of riparian forest; the Maple River aquaduct would impact approximately 3 acres of riparian forest; the storage area would impact 40 acres upland forest; and the Red River outlet structure would impact 9 acres of riparian forest. There would be no impacts to forests at the Lower Rush and Rush rivers.

Table 47 - Impacts to Forested Land with FCP

Forest Impacted FCP			
Riparian Forest Impacted	Acres	Upland Forest/Shelter Belts	Acres
Red River Control Structure Impacts MN	22	Red River Control Structure Impacts MN	0
Red River Outlet Structure Impacts MN	18	Red River Outlet Structure Impacts MN	0
Diversion Channel MN	2	Diversion Channel MN	47
Total	42	Total	47

Table 48 - Impacts to Forested Land with ND35K

Forest Impacted ND35K			
Riparian Forest Impacted	Acres	Upland Forest/Shelter Belts	Acres
Red River Control Structure Impacts ND	20.4	Red River Control Structure Impacts ND	0
Red River Outlet Structure Impacts ND	9	Red River Outlet Structure Impacts ND	0
Wild Rice River Control Structure Impacts ND	20	Wild Rice River Control Structure Impacts ND	1
Sheyenne River Aquaduct Impacts ND	9.8	Sheyenne River Aquaduct Impacts ND	0
Maple River Aquaduct Impacts ND	3.1	Maple River Aquaduct Impacts ND	0
Diversion Channel ND	55	Diversion Channel ND	40.5
Total	117.3	Total	41.5

Table 49 - Impacts to Forested Land with LPP

Forest Impacted LPP			
Riparian Forest Impacted	Acres	Upland Forest/Shelter Belts	Acres
Red River Control Structure Impacts ND	20.4	Red River Control Structure Impacts ND	0
Red River Outlet Structure Impacts ND	9	Red River Outlet Structure Impacts ND	0
Wild Rice River Control Structure Impacts ND	20	Wild Rice River Control Structure Impacts ND	1
Sheyenne River Aquaduct Impacts ND	9.8	Sheyenne River Aquaduct Impacts ND	0
Maple River Aquaduct Impacts ND	3.1	Maple River Aquaduct Impacts ND	0
Diversion Channel ND	55	Diversion Channel ND	41
		Storage Area	40
Total	117.3	Total	82

The loss of these wooded areas would be permanent but would be mitigated for by converting farmed wetland along the Red River into floodplain forest at a 2:1 ratio. There will also be tree plantings along the recreational corridor. A discussion of the mitigation proposals and methods for calculating acres is in Attachment 6. The other upland areas to be disturbed are currently farmed and have reduced natural resource value. Portions of the spoil areas would be available for farming after completion. All other disturbed areas would be replanted with native species, primarily grasses that would have positive impacts on the area's overall habitat value. Overall, the construction activities would have temporary adverse impact on the terrestrial habitat but the eventual changes in vegetative cover would have long term beneficial impacts on the avian and small mammal groups which are found in areas on the periphery of residential development and agricultural plots.

5.2.1.9 Endangered Species

5.2.1.9.1 Federal Species

Two federally-listed threatened or endangered species are listed for Cass and Richland Counties: the whooping crane (*Grus americanus*) and the Gray Wolf (*Canis lupus*), both of which are endangered. One federally-listed threatened or endangered species is listed for Clay County: the Western prairie fringed orchid (*Platanthera praeclara*), which is threatened. One species is on the candidate species list for Clay County, the Dakota skipper (*Hesperia dacotae*). No species are listed for Wilkin County, Minnesota. The Fish and Wildlife Service's records do not indicate any individuals of any of these species within the study area for any of the diversion channel alternatives (FWS letter in Appendix Q).

Bald eagles and their nests are protected from take and disturbance, respectively, per the Bald and Golden Eagle Protection Act. The Fish and Wildlife Service verified the location of two bald eagle nests within the study area inside of the protected area of the ND35K and LPP, but several miles from any proposed construction, and a third nest has been identified approximately 5 miles upstream of the Red River control structure that may be impacted by the LPP due to staged water.

The three nests will not be impacted by the project construction due to location, but the three nests will be monitored during the spring before construction. Nests were monitored in the spring of 2011 and only two nests remain. In addition, the study area will continue to be monitored during the upcoming years to ensure that no new nests will be impacted by project construction. The nest located upstream of the control structure may be impacted by staged water weakening the root system of the tree. This is highly unlikely due to the frequency of events that require staging, however if there is an extreme event year after year there could be an impact. There will be raptor nest surveys completed in the spring of the year preceding construction within or near any affected wooded areas.

5.2.1.9.2 State Listed Species
5.2.1.9.2.1 Minnesota Special Concern Species and Threatened and Endangered Species with Potential to Occur in Clay County

There are several species on either the Special Status species list or the Threatened and Endangered Species list with potential to occur in Clay County, Minnesota (see Section 1.9 Appendix F). Of these species listed there are is one bird species (bald eagle), one fish species (lake sturgeon), and one mussel species (black sandshell) with moderate potential to occur within our study area. The other species listed either have no potential or low potential of occurring within in the study area.

Impacts to the bald eagle are addressed in section 5.2.1.10.1. Direct impacts to the lake sturgeon would likely be minimal as the lake sturgeon would avoid construction activity. The ability for lake sturgeon to migrate could be occasionally affected during operation of the structure. These impacts are outlined above for each diversion channel alternative. Impacts to lake sturgeon would likely be less than significant for each alternative, following construction of all project features (e.g., fish passage channels) and mitigation features outlined for each alternative.

In-water construction activities under any diversion channel alternative could result in mortality of black sandshell mussels. Previous mussel surveys have collected black sandshell from the Red River in the study area. Additional mussel surveys are being considered for project footprint areas to verify whether impacts to mussel resources would be substantial.

5.2.1.9.2.2 North Dakota Special Status Species with Potential to Occur in Cass County
There are several Special Status Species with potential to occur in Cass County, North Dakota (see section 1.9 Appendix F). Of these listed species, five have a moderate potential of occurring within the study area. The other species listed either have no potential or low potential of occurring within in the study area.

The five species that have a moderate chance of occurring in the study area include two bird species (whip-poor-will and a cardinal), and three mussel species (Wabash pigote, black sandshell, and the mapleleaf).

Habitat used for nesting by either the cardinal or the whip-poor-will may be disturbed or removed during project construction. To the extent practicable, vegetation clearing activities would be done so as to avoid affecting nesting individuals. Nonetheless, some limited take of individuals may occur incidental to construction activities. It is expected that any limited take would have no long lasting effect on the affected migratory bird species.

Forested land that will be impacted as part of the project will be impacted during the winter months in order to not impact the bird species during their nesting and rearing periods. This action will minimize the risk of any impacts to either listed bird species.

In-water construction activities under any diversion channel alternative could result in mortality of black sandshell, mapleleaf and Wabash pigtoe mussels. Previous mussel surveys have collected these species from the Red River in the study area. All three have been collected from the Sheyenne River in the vicinity of the proposed aqueduct. Black sandshell have been collected from the Wild Rice River in the area of the control structure for the ND35K and the LPP. Additional mussel surveys are being considered for project footprint areas to verify whether impacts to mussel resources would be substantial.

5.2.1.10 Prime and Unique Farmland

Maps of the FCP, ND35K and LPP were sent to the Natural Resources Conservation Services (NRCS) in both North Dakota and Minnesota. NRCS evaluated these footprints for the Farmland Conversion Act and made determinations for each of these alternatives. For the FCP approximately 5,889 acres would be impacted, for the ND35K up to 6,540 acres of prime and unique farmland would be impacted, and for the LPP approximately 6,878 acres of prime and unique farmland would be impacted. (Appendix F sections 1.4 and 1.5). The staging area of the LPP was not analyzed for prime and unique farmland because these lands will generally not be removed from production.

For all of the diversion channel alternatives there will be a great deal of prime and unique farmland impacted, as the majority of the land impacted is farmland, and of that farmland over 95-percent of it is considered prime and unique for the FCP and over 90-percent is considered to be prime and unique for the LPP and ND35K. This impact is considered to be less than significant based on the large quantity of farmland in the study area and the fact that over 90-percent of all farmland is considered prime and unique in this region.

5.2.1.11 Hazardous, Toxic and Radioactive Waste (HTRW)

A Phase I Environmental Site Assessment (ESA) was completed for both the Minnesota and North Dakota diversion channel alternatives in December 2010. It conformed to ASTM Standard Practice E1527-00. The ESA recommended a limited Phase II Environmental Site

Assessment depending upon the ultimate selected diversion alternative. Detailed information will be made available upon request.

For the LPP a Phase I Supplemental HTRW will be completed to include the areas that were not identified in the December 2010 report. These areas include the alignment shift along the northern portion of the diversion, the extensions on the tie-back levee in Minnesota, the tie-back levee along Hwy 17, the storage area and the staging area.

5.2.1.12 Climate

Climate change has become an area of concern due to the potential for effects on numerous aspects of the environment, especially those related to water resources. The U.S. Global Change Research Program (USGCRP) has summarized information regarding climate change and its potential effects in regional assessments (http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts). The project area is in the northern area of the Great Plains region, which extends from North Dakota and Montana, south through Texas. Relative to the baseline of the 1960s and 1970s, average temperatures of the Great Plains has risen about 1.5°F. Depending on modeling assumptions, average temperatures in the Great Plains are projected to rise an additional 1.5°F to 11.5°F by 2090. Additionally, precipitation is projected to change, particularly in winter and spring, with wetter conditions projected to occur in the northern Great Plains. In North Dakota, rainfall is projected to increase by about 10%-30% by 2090, depending on modeling assumptions. Also, more frequent extreme events such as heat waves, droughts, and heavy rainfalls are projected there.

If the predicted wetter conditions occur in North Dakota as a result of climate change, there would also likely be an increase in the probability that the Fargo Moorhead Metropolitan area will continue to experience flooding. The need for the project is based on current climate conditions, and any increase in future precipitation would only serve to increase the probability that the flood stages will continue to increase. Therefore, consideration of future climate change and its effects would not contradict the need for the project, and given the uncertainty associated with climate change it would not affect the reasoned choice among alternatives.

On 28-29 September 2009, the St. Paul District conducted an Expert Opinion Elicitation (EOE) on increasing flood flows on the Fargo, ND-Moorhead, MN flood risk management project. Six Federal experts and 6 Observers addressed this issue including climate change impacts. For a full account of this proceedings refer to Appendix A-1B. For a full account of the methodology developed to implement the panel's recommendations, see Appendix A-1c.

5.2.2 Cultural Resources

Most lands in Cass County, North Dakota, and Clay County, Minnesota, have not been surveyed for cultural resources. Previous cultural resources surveys conducted in these two counties have usually been related to specific projects or studies, e.g., Red River bank stabilization in Fargo and Moorhead; Cenex pipeline construction; Fargo Southside Study Area; and West Fargo Flood Control Project. Inventories of potentially historic standing structures were undertaken in Cass County in 1979 and the City of Fargo in 1985 under the sponsorship of the Historic Preservation

Division of the State Historical Society of North Dakota (Fiege 1986; Granger 1986; Ramsey 1979), and in the City of Moorhead in 1979 and other Clay County communities in the 1980s under the sponsorship of the State Historic Preservation Office of the Minnesota Historical Society (Moorhead Community Development Department 1979). Few of those structures have been evaluated for eligibility to the National Register of Historic Places (National Register). Since the 1980s additional structures have reached 50 years old and need to be recorded and evaluated as well. Specific effects on cultural resources for each of the diversion channel alternatives are given below. Appendix E, Cultural Resources, contains more detailed information on known cultural resources sites, reported but unverified site leads, and previous cultural resources investigations for each diversion channel alternative.

The area of potential effect for each alternative includes one-half mile on either side of the diversion channel centerline, one-quarter mile on either side of a breakout channel centerline, and one-sixteenth mile on either side of a tie-back levee centerline. A Programmatic Agreement for the project was negotiated between the St. Paul District, U.S. Army Corps of Engineers, the Minnesota State Historic Preservation Officer, and the North Dakota State Historic Preservation Officer, with the City of Fargo and the City of Moorhead, being the non-federal sponsors, as concurring parties. The Cass County and Clay County Board of Commissioners, along with certain Indian Tribes, may also elect to be concurring parties. The Programmatic Agreement will cover the Section 106 of the National Historic Preservation Act responsibilities of the Corps for this project. A draft of the Programmatic Agreement is included as Attachment 3.

A Phase I cultural resources survey of the proposed diversion alignments and tieback levees on both the North Dakota and Minnesota sides of the Red River consisted of a walkover of the project area by archeologists to identify and record any surface-visible prehistoric and historic archeological sites. Subsurface testing during the survey involves small hand-dug shovel holes or soil auger holes to identify shallowly buried prehistoric archeological sites and soil cores to identify more deeply buried sites. The purpose of this survey is to locate and record both prehistoric and historic archeological sites and any standing structures over 50 years old. The next step will be to do testing and archival research for any archeological sites found in the selected alignment to determine if they are eligible for inclusion on the National Register of Historic Places. Archival research and interviews on the history of any 50 year old or older structures, including farmsteads, will be conducted to determine if they meet any of the eligibility criteria for listing on the National Register (i.e., the site/building is associated with significant historic events; is associated with important persons; has a distinctive type, period or method of construction, is the work of a master architect, possesses high artistic values, or represents a significant and distinguishable entity whose components may lack individual distinction; and/or has the potential to provide information important to history or prehistory). Finally, any archeological sites and architectural structures listed on or determined eligible to the National Register which will be impacted by the diversion construction will have to have those impacts mitigated prior to diversion or tieback levee construction in that area. Mitigation for eligible or listed prehistoric or historic archeological sites generally consists of data recovery excavation of a portion of the site. Mitigation for historic architectural sites generally consists of large-format photography and measured drawings of any buildings and structures, a scaled planview map of a farmstead layout, and a written history of the site. Native American tribes with historic ties to the Red River Valley are also being consulted regarding locations in the project area which are important to them either currently or historically.

5.2.2.1 ND35K Plan

As of March 8, 2011, there are no National Register listed historic properties in the ND35K alignment. The Sheyenne River Bridge (32CS4462) in Warren Township has been determined eligible to the National Register. Prehistoric archeological sites 32CS42 and 32CS44 have been determined not eligible to the National Register. Prehistoric archeological sites 32CS43 and 32CS201 and historic standing structures 32CS4461 (Maple River bridge in Raymond Township), 32CS5090 (rural residence), and 32CS5091 (rural residence) have not had their National Register eligibility evaluated. A lead to one historic archeological site—32CSX238b-Red River Trail segment in North Dakota—needs to be field verified. None of these known sites or structures is crossed by the diversion channel. The tie-back levee alignment crosses where the historic oxcart trail (21CYr-Red River Trail) ran north-south along the Minnesota side of the Red River. The continued existence of the Red River Trail in this area needs to be field verified. Of the known sites and structures in the ND35K diversion channel alignment, only site 32CS42 is crossed by the diversion channel. Site 32CS42 has been determined not eligible for the National Register. This diversion channel alignment needs a Phase I cultural resources survey, except for where it intersects the existing West Fargo diversion channel. The Phase 1 survey has been partially completed; the results can be made available upon request. The entire tie-back levee footprint needs to be surveyed. A partial survey of the diversion channel and tie-back levee alignments in 2010 recorded seven historic archeological sites, one isolated prehistoric projectile point, three isolated historic artifacts, 11 farmsteads, two railroad segments, and four other structures. Of these, two farmsteads (ND-5 and ND14), one railroad segment (FM3-5), and one historic archeological site (FM2-2) are recommended eligible to the National Register; six farmsteads (ND-3, ND-4, ND-7, ND-10, ND-12 and ND-13) have undetermined National Register eligibility. The remaining eight structures, six sites, and four isolated finds are recommended as not eligible to the National Register.

5.2.2.2 FCP

As of March 8, 2011, the John Olness House (CY-KRG-001) on U.S. Highway 75 at Kragnes is the only National Register listed historic property in the FCP alignment. Prehistoric archeological sites 21CY3, 21CY19 and 21CY55 and three historic standing structures (CY-DWC-003-Northern Pacific shop buildings; CY-KRG-004-Kragnes Bar; CY-KRG-005-warehouse in Kragnes) have not had their eligibility to the National Register evaluated. Leads to three historic ghost towns (21CYk-Ruthruff, 21CYl[el]-Lafayette, and 21CYo-Burlington) and to 21CYr, the Red River Trail, an historic oxcart running along the east side of the Red River, need to be field verified. This diversion alignment crosses the locations of the historic ghost towns of Ruthruff and Lafayette as well as crossing the Red River Trail three times. The breakout channel alignment crosses the location of the historic ghost town of Burlington (21CYo) and follows the Red River Trail (21CYr) for roughly one mile and crosses it once further south as well. The location of an unverified lead to one historic archeological site (32CSX1-Holy Cross Mission) is crossed by the FCP tie-back levee alignment, which is in North Dakota. The diversion alignment, the breakout channel alignment, and the tie-back levee alignment all need a Phase I cultural resources survey. The Phase 1 survey has been partially completed; the results can be made available upon request. The existence of the various ghost towns, the mission site, and the Red River Trail in this area needs to be field verified if this alternative is selected. A partial survey of this diversion channel alignment and its associated Red River and Wild Rice River breakout channel alignments and tie-back levee alignment in 2010 recorded seven historic archeological sites, one prehistoric and historic archeological site, three isolated prehistoric artifacts, 14 farmsteads, five houses, and two other structures. Of these, two farmsteads (MN-14 and MN-19), two historic archeological sites (FM2-4), and the prehistoric and historic archeological site (FM4-3) are recommended as eligible to the National Register; one farmstead (MN-6) and a railroad segment (MN-8) are of undetermined eligibility to the National Register. The remaining five archeological sites, 17 structures and three isolated finds are recommended as not eligible to the National Register.

5.2.2.3 LPP

There are five prehistoric archeological sites, one prehistoric isolated find, nine historic archeological sites, three historic isolated finds, four historic archeological site leads, 13 farmsteads, and six other structures within one half mile either side of the LPP diversion channel centerline, within 100 meters/330 feet of either side of its two tie-back levee centerlines, in Storage Area 1, or within 100 meters/330 feet of the exterior boundary of Storage Area 1. As of March 8, 2011, there are no National Register of Historic Places listed historic properties present in the LPP alignment. Bridge site 32CS4462 has been determined eligible to the National Register and historic archeological site FM2-2 and two farmsteads (ND-5 and ND-14) and a segment of railroad (FM3-5) have been recommended as eligible to the National Register. Prehistoric archeological sites 32CS43, 32CS201 and 32CS4563, church site 32CS114, farmsteads ND-3, ND-4, ND-7, ND-10, ND-12 and ND-13, and unverified historic site leads 32CSX33, 32CSX131, 32CSX238b, and 21CYr have not had their National Register eligibility evaluated. Prehistoric archeological sites 32CS42 and 32CS44 have been determined not eligible to the National Register in 1988 in conjunction with the Horace-West Fargo Flood Control Project. The remaining eight archeological sites, four isolated finds, and 10 structures are recommended as not eligible to the National Register.

5.2.2.4 Cemeteries

There will be no impacts to cemeteries from construction of the ND35K diversion channel and associated tieback levee where proposed.

There will be no impacts to cemeteries from construction of the FCP diversion channel, and its associated breakout channels and tieback levee. Holy Cross Cemetery and St. Benedict's Church Cemeteries are outside the construction limits of the tieback levee and will not be affected. The tieback levee will be visible from both of these cemeteries.

There will be no impacts to cemeteries from construction of the LPP diversion channel and disposal berms, from construction of the Minnesota tieback levee, from construction of the County Road 17 tieback levee, or from construction of the Storage Area #1 exterior dike. St. Benedict's Church Cemetery, just east of the storage area, will be avoided by construction activities. The storage area dike will be visible from that cemetery or as a backdrop to that cemetery and St. Benedict's Church when looking west from I-29 and from County Road 21 (38th Street South).

The twelve cemeteries in the upstream staging area will be variously affected with the LPP in place (see Chapter 4). During the 1-percent chance event, there will be no additional water at the Pioneer Cemetery and Schmitt Cemetery in North Dakota and the Wolverton City Cemetery in Minnesota. There will be up to 0.30 foot (3.6 inches) of additional water at the South Pleasant Cemetery and the Smith Cemetery in North Dakota. There will be up to 1.00 foot of additional water at the Christine Cemetery in North Dakota. There will be up to 3.00 feet of additional water at the North Pleasant Cemetery, Hemnes Cemetery, and Eagle Cemetery in North Dakota and the Comstock Cemetery in Minnesota. Finally, there will be from 3.01 to 9.35 feet of additional water at the Hoff Cemetery and Clara Cemetery in Minnesota.

Impacts to these cemeteries from flooding or from longer flooding may include difficulties keeping the grass, bushes and trees alive and post-flood cleanup of flood-deposited sediment. Depending upon the speed of the floodwater, there is potential for headstones being tipped over or for erosion of soils. Access to a cemetery may be lost during periods of high water even if the cemetery itself is not affected.

Each cemetery will have to be looked at on a case-by-case basis to determine what impact mitigation measures may be necessary. Information needed for each cemetery includes its location and size, the number of individuals buried there, the elevation of the cemetery (when does it start flooding), the type of headstones or monuments present (will they stay in place or would moving floodwater tip them over or move them), whether it is a family cemetery, a church cemetery, or a community cemetery (who has the records so families can be notified if relocation is needed), and whether it is an active or inactive cemetery.

Potential solutions to floodwater damage include construction of a ring levee around the cemetery and relocation of the cemetery. A ring levee would protect the cemetery from flooding, especially if it is not flooding now. This may involve having to purchase land around the cemetery on which to construct such a ring levee. Access to a ring-leveed cemetery would be by a road ramped over the top of the levee. Levee height would vary from cemetery to cemetery depending upon the expected depth of flood waters during a 1-percent chance event with the LPP in place.

Relocation of a cemetery is covered by specific Minnesota and North Dakota state laws. Cemetery relocation would probably be the mitigation measure considered where there is potential for erosion of the cemetery or where the depth of additional water with the project in place during a 1-percent chance event is over three feet. For North Dakota, the Department of Health is involved in burial and cemetery relocation. Actual relocation must be done by a licensed mortician. Families and descendents of the individuals to be relocated have to be notified and their permission to relocate their deceased relatives acquired. Their preference for a reburial location would be determined. Relocation costs for each cemetery are based on the number of individuals to be relocated. Specific costs include family notification costs, removal costs, transport costs, and costs associated with acquiring land for a new cemetery or cemetery plots in one or more existing cemeteries for reinterment. If a cemetery is to be relocated, the families will be notified of when the actual relocation will take place and when and where the reburial will take place so they may pay their respects before relocation starts and after or while the deceased are reburied.

5.2.3 Socioeconomic Resources

5.2.3.1 Social Effects

5.2.3.1.1 Noise

During project construction temporary increases in noise are expected from the operation of construction equipment. No increases in noise are expected during project operation.

5.2.3.1.2 Aesthetics

Any of the diversion channel alternatives would result in changes to the landscape near Fargo or Moorhead. The diversion channel would be vegetated with native species but would still be visible as man-made structures.

5.2.3.1.3 Recreational Opportunities

Recreational opportunities will not be adversely impacted by any of the diversion channel alternatives. Recreation plans have been developed for both Minnesota and North Dakota diversion alignments and are described in Appendix M. Recreation plan features contain multipurpose trails, interpretive signage, benches, trash receptacles, two pedestrian bridges, three trailheads with parking facilities and two car/trailer parking facilities. The trailheads would also include potable water, picnicking, restrooms, interpretive kiosks and landscaping. The recreation plan could result in a healthier, more vibrant community accenting the current growth trends of the region. The plantings associated with the recreation will make the recreational opportunities more visually pleasing and will help to enhance the overall experience.

5.2.3.1.4 Transportation

A number of rural section line roads will be impacted with the construction any diversion channel alternatives. Some roads will be cut off at the diversion channel. The Minnesota diversion alignment intersects approximately 30 roads, as does the North Dakota alignment. New bridges across either diversion channel alignment are planned for a minimum of every three miles. For the FCP, there would be 20 bridges across the channel. For the LPP and ND35K there would be 19 bridges across the channel. The LPP requires a raise of Interstate 29 through the staging area.

Table 50 and Table 51 detail the locations and sizes of the bridges for the FCP and the LPP respectively. Chapter 3 displays maps of each alternative with the locations of the bridges. Either diversion alignment would result in the modification of traffic patterns for local residences and farmsteads that are close to the alignment. There would be little disruption to through traffic. In some locations, farm fields will be bisected by the diversion channel, which will result in additional transportation time for farm equipment. It is anticipated that over time farmers will exchange land so that the time they spend in transit across the diversion alignment is minimized.

For the LPP, a large amount of land upstream of the diversion inlet will be used for staging water during high flows. As a result, a number of residences and farmsteads will be acquired. Traffic patterns in the staging area will change permanently. Much of this area, currently used for access to local residences, will be used as a throughway for those commuting to and from the metro area on Interstate 29, or to and from locations to the east or west. During high flows, water in the staging area will prevent commuting along East –West routes. Interstate 29 and Minnesota Highway 75 will be elevated so that traffic can continue during high flows. The railroad bridge would also be raised.

For the FCP and ND35K the maximum stage increases downstream at the 1-percent chance event are 12.5 inches and 25.4 inches, respectively. The increase in duration would be negligible. Stage increases would restrict access to roads and buildings downstream more so than under existing conditions.

With any of the diversion channel alternatives in place, the need to close highway and railroad bridges and the airport during high water events would be significantly diminished when compared to the without project condition.

Project construction could have some short-term minor negative impacts on normal community traffic patterns due to the construction activity and truck hauling. These effects would be attenuated through the appropriate placement of construction and safety signage and use of road detours. These effects would be temporary and would terminate when project construction is complete.

Bridges will be constructed at a minimum of every three miles to cross the proposed diversion channel. These bridges will provide access for emergency vehicles, school bus routes, and more. Standard safety rules, laws and regulations for highway travel with heavy equipment will have to be complied with. Standard safety rules, laws and regulations will be applied to raised highways. There are no local road raises planned as part of the project. Local roads will remain the responsibility of local communities and additional bridges can be constructed at non-Federal expense.

Table 50 - Minnesota Diversion (FCP) Alignment - Bridge Locations and Sizes

Bridge Location FCP	Estimated Bridge Length (ft)	Bridge Deck Width (ft)
Interstate 29 South Bound	300.6	44.5
Interstate 29 North Bound	300.6	44.5
110th Ave S.	415.6	34.5
US Highway 75	690.9	50.5
80th Ave S	803.2	34.5
60th Ave S	800.8	34.5
County-State Highway 52	817.6	34.5
50th Ave S	827.4	34.5
Interstate 94 East Bound	867.4	44.5
Interstate 94 West Bound	867.4	44.5
US Highway 10 East Bound	911.6	44.5
US Highway 10 West Bound	911.6	44.5
28th Ave N	889.0	34.5
57th Ave N	706.7	34.5
40th St N	697.2	34.5
90th Ave N	684.7	34.5
100th Ave N	681.0	34.5
US Highway 75	677.3	50.5
110th Ave NW	666.7	34.5
15th St NW	640.2	34.5

Table 51 North Dakota Diversion (ND35K & LPP) Alignment – Bridge Locations and Sizes

Bridge Location LPP & ND35K	Estimated Bridge Length (ft)	Bridge Deck Width (ft)
County Road 81	605	38.5
Interstate 29 North Bound	583	42.5
Interstate 29 South Bound	582	42.5
48th St SE	431	32.5
170th Ave SE	641	30.5
46th St SE	752	32.5
44th St SE	702	30.5
41st St SE	640	38.5
Interstate 94 East Bound	689	42.5
Interstate 94 West Bound	689	42.5
36th St SE	659	38.5
33rd St SE	632	38.5
31st St SE	613	30.5
28th St SE	615	30.5
Interstate 29 South Bound	586	42.5
Interstate 29 North Bound	586	42.5
County Road 81	587	38.5
25th St SE	588	32.5
173rd Ave SE	593	30.5

5.2.3.1.5 Public Health and Safety
For the metro area, all of the diversion channel alternatives would have significant beneficial effects on public health and safety by significantly reducing the risks of loss of life and property damage attributable to the effects of flooding. Flood risk management would minimize the

adverse effects that have occurred to communities in the Red River Valley during recent flood events including: large-scale community evacuation, potential contamination of the drinking water supply, spoilage of food through loss of refrigeration or floodwater contamination, lack of access to health care, evacuation of hospitals and nursing homes, and stress and trauma. Flooding of buildings introduces multiple contaminants into the water including sewage, fuel oil, pesticides, and solvents. The cleanup of flooded structures exposes individuals to potential adverse health effects from exposure to contaminants, bacteria, and molds. All of the diversion channel alternatives would reduce the likelihood of these adverse effects of flooding.

The structure on the Red River will be treated as if it were a bridge for the majority of the time and recreational boats will be able to pass underneath it as they please. While the project is in operation recreational boaters will not be allowed to pass underneath the structure or to go within a to-be-determined distance of the structure for safety reasons. Appropriate signage and educational information regarding the Red River and its tributaries will be available to the public as the project moves forward.

For the areas downstream, the FCP and ND35K have adverse impacts on public health and safety due to stage increases. Impacts on public health and safety are expected to be minor.

For the communities upstream the LPP will require a number of fee acquisitions in the staging area. Health and safety in this area will be benefited due to the removal of some homes and businesses from the flood prone areas. Homes and businesses that are not bought out may have other mitigation features (such as ring-levees). Buildings with no mitigation would experience increases in risk of flooding. For major flood events, there will be a large staging area for a number of days or weeks that will pose a safety concern. Appropriate safety measures will be implemented to minimize risks from the staging area. Design criteria will need to be appropriate to minimize the possibility of failure for the control structures and the tie-back levees.

Mosquitoes are present in the study area, including vector species, which can carry West Nile Virus or other viruses. For all three diversion channel alternatives there is potential for mosquito habitat to be created within the wetlands along the bottom of the diversion channel. There is a likelihood that the side slopes and spoil piles of the diversion will displace mosquito habitat. Overall, it is unlikely that there would be a noticeable net change in mosquito habitat due to the channels. For the LPP, water would be retained in the staging area and Storage Area #1. At a 10-percent chance event, approximately 10,700 acres would be inundated for an extra 5 to 12 days. For larger events larger than the 10-percent chance event there would likely be similar impacts for up to 25,000 acres. It is unclear how much additional mosquito habitat will be created in the staging and storage areas and how this will affect vector species. Currently Fargo ND, Moorhead MN and Cass County are part of a mosquito spraying program to decrease hazards from vector mosquitoes; this plan would be adjusted to include any areas where the project would result in additional mosquito habitat.

5.2.3.1.6 Community Cohesion (Sense of Unity)

All of the diversion channel alternatives, by providing increased protection from future floods, would enhance community stability in the metro area. With increased security, residents would be less likely to relocate. Similarly, they would be able to devote greater attention to other community issues and needs. The Fargo-Moorhead Metropolitan Area as a whole should become more cohesive after project construction, but some areas would lose the cohesion that they have had. In particular, the areas bisected by the diversion channel will have loss of cohesion. These include rural areas with farmsteads and farm fields.

For the FCP and ND35K, downstream areas may experience loss of cohesion due to stage increases. Additionally, downstream impacts will be seen as a gain for the metro area at the expense of the communities downstream. This may have a divisive effect between citizens in the downstream communities and the metro.

For the LPP many residents in the staging area will need to be relocated. The relocation of many residents will have adverse impacts to community cohesion, and will impact school districts and local government entities.

5.2.3.1.7 Community Growth and Development
The Fargo-Moorhead Metropolitan Area is expected to continue to grow at a rapid rate with or without a project. All of the diversion channel alternatives are expected to have a beneficial effect on the growth and development of the Fargo-Moorhead Metropolitan Area. Provision of this level of flood risk management will likely foster investment in homes, businesses, and community infrastructure.

The FCP would have an adverse impact on the future development area for the city of Dilworth, where the diversion channel footprint divides the city's future development area in half.

For the FCP and ND35K, the communities downstream would experience stage increases. This would be associated with additional flood risk and would have a minor impact on property values and future demand for development.

For the LPP some homes and businesses upstream in the staging area would require fee acquisitions, and some buildings would have other mitigation features. Several hundred or thousands of residents would need to be relocated and the area would not be able to be used for development.

There would be temporary impacts to civic planning due to fee acquisitions and loss of tax base for the LPP. The Kindred School District's plan for a new school would be impacted in the short term due to a potential loss of tax base and diminished student body.

School districts in the upstream area, such as Kindred and Richland, may experience changes in student population; however the extent of these changes and resulting impacts are not definitively known. Area residents who are relocated may choose to keep children enrolled in the same school, resulting in very minimal impacts to school districts; however, some students may enroll in a different school. Such shifts in student population from one school system to another are considered regional transfers; as such, there is no gain or loss to the national economy overall. Although the LPP may have impacts to the tax valuation of properties in the school district, the potential loss of tax revenue is not compensable as part of the cost-shared Federal project. The Corps encourages school districts to work with the Metro Flood Study Work Group to ensure that any items that cannot be addressed by the Federal project be discussed at the local level.

5.2.3.1.8 Business and Home Relocations
The LPP will require a substantial number of relocations for communities in the staging area.

All diversion alternatives will require a small number of relocations for those structures that the channel right-of-way intersects.

Because the affected owners will be covered by P.L. 91-646 (Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970), they should not experience direct financial loss from the relocations.

For residents and business owners, relocation can be stressful. Many individuals have lived in the area for a long time and may be attached to their homes or businesses.

The process of acquiring property for a project is highly regulated. The Fifth Amendment of the Constitution states that private property shall not be taken for public use without just compensation. To address what constitutes just compensation, Congress passed the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 ("Uniform Act"). The non-federal sponsors will be required to follow the Uniform Act in acquiring any lands. The Corps of Engineers will work with the non-federal sponsors to ensure the correct process and procedures are adhered to throughout the process.

The exact timing of any buyouts, and whether buyouts will even be necessary, is unknown at this time. The project is only in the feasibility stage, and buyouts are contingent upon Congress authorizing and funding the project. Mitigation for the project cannot begin until the project has been authorized and funded. Once the project is approved and funded each affected parcel will be appraised and assessed for impact. Each parcel is unique and distinctive and must have a determination made as to how to mitigate project effects and compensate the owner for damages.

Real estate acquisitions are the responsibility of the non-federal sponsors. The non-federal sponsors will establish timetables for real estate acquisitions once the project has been authorized and funded based upon the needs of the project and available resources. Local communities should work with the sponsors to address issues related to the timing of required buyouts. Each affected parcel will be appraised and assessed for impact. Each parcel is unique and distinctive and must have a determination made as to the most appropriate way to mitigate project effects and compensate the owner for damages.

If a farm must be relocated, the non-federal sponsors will help identify suitable replacement property for the operation. As such, the property owner will be entitled to receive relocation advisory services that include: 1. A full explanation of relocation benefits for the particular situation; 2. A discussion about the operation and what is needed for a successful relocation; and 3. A current listing of suitable properties.

Part of the process will be an appraisal, which determines the fair market value of the property. Fair market value is an estimate of the market value of a property based upon what a knowledgeable, willing, and unpressured buyer would pay. The appraisal will attempt to take all objective property features into account when determining fair market value. The fair market value is determined without consideration for the effect the project has had on the value of the land. For more information on the process for acquisitions please go to: http://www.fhwa.dot.gov/realestate

5.2.3.1.9 Existing and Potential Land Use
Along with the aforementioned relocations, land use changes could occur along and near the proposed diversion alignments with the purchase of project right-of-way, although farming will be allowed on the landward side slopes of the diversion channel spoil banks.

For the LPP some of the staging area will not be able to be used for residential or retail zoning. There are opportunities to convert this area to wetlands, grasslands, wooded areas or other uses (a significant part of the staging area is currently farmland).

Land in the channel right-of-way would be impacted. An estimated 5,889 acres of prime farmland would be directly or indirectly impacted with the construction of the FCP, while the ND35K would impact 6,540 acres and the LPP would affect 6,878 acres. This includes less than ½-percent of the total cropland in Cass and Clay counties. Owners of agricultural lands that are purchased for the project would be compensated at fair market value.

The both alignments are expected to split or divide farms into separate parcels. In some cases, farmers would have to detour around the diversion channel using established roadways or specially constructed access roads to access their property and conduct farming operations. The number of farms under active use that would be divided by the proposed right-of-way is unknown at this stage. Mitigation measures would be incorporated into the final design to minimize impacts to farmland.

5.2.3.1.10 Impacts to Existing Memorials
Two known memorial monuments exist in Oxbow, North Dakota, and it is possible that additional memorials could be identified during project design and implementation. The known monuments are the Oxbow Community Memorial Park and a stone monument at the Oxbow Country Club. Both of these memorial monuments are dedicated to former citizens of Oxbow. Physical impacts to these memorials from flooding in the staging area are not likely to be significant, but relocating residents away from the City of Oxbow would remove them from proximity to these memorials and make routine maintenance more difficult. Mitigation for monuments and memorials will be determined on a case-by-case basis during the design and implementation phase. If it is determined that mitigation is necessary, mitigation could include raising or relocating the monument features, constructing ring levees, or other nonstructural measures.

5.2.3.2 Economic Effects

5.2.3.2.1 Property Values

For the metro area all of the diversion channel alternatives are expected to have a beneficial effect on currently developed community property values because of the decreased risk of flood damage, along with the lessening of restrictions on improvements that can be made to existing developments in the floodplain. Developable lands within the protected area would retain or increase in property value through removal of the risk of flood damage. There would no longer be a need to raise or flood-proof new construction. New development or intensification of existing development should be pursued only in a manner that retains awareness and sensitivity to the residual flood threat. These beneficial effects will be greater for the ND35K and LPP as they provide flood risk management for a larger area.

For the FCP and ND35K, property values will be adversely impacted in the downstream area. The magnitude of impacts to property values is expected to be small. For landowners outside the benefited area that experience increased flood stages when compared to the current without project condition, further analysis will be undertaken to determine if there has been a taking. For any properties that are deemed to have incurred a taking, compensation would be provided as required by the Fifth Amendment of the U.S. Constitution.

For the LPP there may be impacts to property values due to fee acquisitions in the staging area, however a number of factors make the reaction in market values unpredictable. These factors include the expectation of locals regarding the timing and implementation of the LPP.

5.2.3.2.2 Tax Revenues

All of the diversion channel alternatives are expected to have a minor beneficial effect on tax revenues in the metro area. The project would preserve property values in benefited developed and developable areas, allow for the redevelopment of marginal properties and attract additional businesses and industry. These beneficial effects will be greater for the ND35K and LPP as they provide flood risk management for a larger area. New development or intensification of existing development should be pursued only in a manner that retains awareness and sensitivity to the residual flood threat. Future tax revenues would be lost from the properties that would be acquired for project construction.

The LPP requires a large amount of land to be purchased for the staging area. This will impact the tax base of local governments and have a short term impact on current planning efforts.

For the FCP and ND35K, the downstream areas will experience a small decrease in property values. Tax revenues will be affected proportionately.

5.2.3.2.3 Public Facilities and Services

All of the diversion channel alternatives could have a substantial beneficial impact on public facilities and services because the potential for damage to public facilities would be reduced, the potential for disruption in the delivery of public services would be reduced, and the public works response to future flood threats would not be as great.

5.2.3.2.4 Regional Growth
All of the diversion channel alternatives would enhance the capacity of Fargo-Moorhead to function as a trade, medical, financial, and cultural center of the region. These will be greater for the ND35K and LPP as they provide flood risk management for a larger area. Growth would continue as projected as indicated in section 4.2.3.

5.2.3.2.5 Employment
For all of the diversion channel alternatives there will be an increase in construction employment during project construction. In addition, the protection provided by the project should contribute to community growth and along with it the associated increases in employment opportunities.

5.2.3.2.6 Business Activity
For all of the diversion channel alternatives, project construction could stimulate local business activity and the protection provided by the project upon completion could provide a climate for business expansion and attraction.

5.2.3.2.7 Farmland/Food Supply
An estimated 5,900 areas of prime farmland would be directly or indirectly impacted by the FCP, while 6,500 to 6,900 acres of prime farmland would be impacted by the ND35K or LPP. Additional farmland in the staging area of the LPP may be converted from farmland. None of the diversion channel alternatives would have an appreciable effect on food supply. A diversion channel would require the purchase of approximately 5,500 to 10,000 acres of agricultural land and disrupt the farming operation of approximately 10 to 15 landowners for the footprint of the channel.

Additional impacts will occur for the LPP, as the staging area may require the acquisition of property interests in as much as 20,000 acres of farmland. Most of the 20,000 acres will likely remain in production long term, but some crop production losses may occur for the years the staging area is operated. Crop losses could occur for up to 20,000 acres if a summer flood event occurs and the staging area is operated. Sedimentation due to staging (spring or summer events) would leave on average less than 0.02 inches of silty clay material across the staging area, with a maximum of 2 inches in localized spots. The deposit of some flood debris could occur in localized spots as well. The effect of small amount of sediment on cropland in the area of the staging area is fairly minor. The material (silty clay) brought in by flood water would be similar to the existing soil in physical and chemical characteristics. This was confirmed by recent research after the flood of 2009. Impacts can range from minor adverse, if weed infestation is a problem requiring added herbicide, to minor beneficial if added fertilizer is brought in with the flood water. Note that sediment from glacial Lake Agassiz is the source of the existing soil, and is credited with the high level of crop fertility in the region. A larger impact due to the staging of water would be the delay in planting of crops due to a prolonged dry-out period, which could occur in years when the staging area operates. A solution for this would be installation of drain tiles (drain tiles are not part of the project features).

Most of the agricultural land is considered to be prime farmland with soybeans and corn as the major crops. Owners of agricultural lands that are purchased for the project would be compensated at fair market value. For situations where the diversion channel would split individual's farmland, the non-federal sponsors may try to facilitate trades so that individuals can keep their property on the same side of the diversion.

5.2.3.2.8 Flooding Effects

All of the diversion channel alternatives would have a significant beneficial impact on flooding effects in the metro area. The project is intended to provide flood risk management from floods, such as the one experienced in 2009, by reducing flood stages within the protected area when compared to the without project condition.

The FCP and ND35K alternatives will increase stages downstream as much as 12.5 and 25 inches, respectively, for the 1-percent chance event. The LPP will have large stage increases in the staging area of as much as 98.8 inches. Table 52 shows the impacts of each plan on homes and other structures upstream and downstream of the metro area. Table 53 shows the impacts of the LPP in the staging area by depth.

Table 52 – Structure Impacts

Flood Impacts on Structures - Red River of the North Abercrombie to Drayton

Structure Type	Existing Conditions 10 percent Flood	FCP 10 percent Flood	LPP 10 percent Flood	ND35k 10 percent Flood	Existing Conditions 2 percent Flood	FCP 2 percent Flood	LPP 2 percent Flood	ND35k 2 percent Flood	Existing Conditions 1 percent Flood	FCP 1 percent Flood	LPP 1 percent Flood	ND35k 1 percent Flood	Existing Conditions 1/5 percent Flood	FCP 1/5 percent Flood	LPP 1/5 percent Flood	ND35k 1/5 percent Flood
	Downstream Area															
	Minnesota															
Residential	103	113	102	110	306	313	309	300	498	534	498	512	769	801	772	774
Farm	483	521	468	499	1,108	1,148	1,111	1,047	1,325	1,422	1,341	1,298	1,900	1,964	1,892	1,800
Commercial/Industrial /Public	23	23	23	23	35	35	35	34	48	49	48	47	105	109	100	107
	North Dakota															
Residential	85	208	86	200	301	328	310	309	410	431	406	410	630	643	633	621
Farm	453	489	430	441	1,056	1,084	1,056	999	1,243	1,313	1,245	1,222	1,717	1,745	1,718	1,651
Commercial/Industrial /Public	2	2	2	2	19	21	21	21	24	25	24	25	43	43	43	43
	Upstream Storage Area 1															
	Minnesota															
Residential	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Farm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Commercial/Industrial /Public	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	North Dakota															
Residential	0	1	19	0	7	15	19	7	14	15	19	14	18	18	19	18
Farm	1	2	74	1	18	38	74	18	53	47	74	53	68	61	74	68
Commercial/Industrial /Public	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Upstream Staging Area															
	Minnesota															
Residential	0	0	3	0	1	2	15	1	2	2	65	2	16	16	72	16
Farm	0	0	9	0	4	4	65	4	15	14	130	15	61	61	141	61
Commercial/Industrial /Public	0	0	0	0	0	0	0	0	0	0	6	0	0	0	6	0
	North Dakota															
Residential	6	7	145	6	74	75	219	74	118	118	233	118	262	274	310	262
Farm	7	7	56	7	68	68	143	68	100	101	148	100	186	190	221	186
Commercial/Industrial /Public	0	0	2	0	1	1	6	1	1	0	52	1	12	12	12	12
	Upstream Area (outside of Staging Area)															
	Minnesota															
Residential	0	0	0	0	3	3	3	3	8	8	9	8	71	71	71	71
Farm	1	1	2	1	10	10	10	10	11	11	11	11	67	67	69	67
Commercial/Industrial /Public	0	0	0	0	0	0	0	0	0	0	1	0	10	10	10	10
	North Dakota															
Residential	0	0	0	0	11	11	15	11	36	36	40	36	99	100	101	99
Farm	4	4	6	4	58	58	60	58	133	130	141	133	302	301	302	302
Commercial/Industrial /Public	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1

Table 53 – LPP 1% Staging Area Structure Impacts

LPP 1% impacts by depth - Upstream Staging Area

Structure Type	Minnesota - 0 to 1 ft. Depth	Minnesota - 1 to 3 ft. Depth	Minnesota - above 3 ft. Depth	North Dakota - 0 to 1 ft. Depth	North Dakota - 1 to 3 ft. Depth	North Dakota - above 3 ft. Depth
Residential	15	44	6	21	0	212
Farm	28	61	41	20	13	115
Commercial/Industrial/Public	2	4	0	0	46	6

5.2.3.2.9 Energy Needs and Resources

All of the diversion channel alternatives would have no appreciable effect on energy needs and resources.

5.2.3.2.10 Floodplain (Executive Order 11988)

Executive order (EO) 11988 was issued by President Jimmy Carter on May 24, 1977 and is entitled “Floodplain Management”. The Corps of Engineers and other federal agencies must comply with EO 11988 when designing or permitting projects. One goal of EO 11988 is to “avoid direct or indirect support of floodplain development wherever there is a practicable alternative.” If avoiding the floodplain altogether is not practicable, EO 11988 requires federal agencies to “minimize potential harm to or within the floodplain.”

5.2.3.2.10.1 No Action Alternative

The study area used for the floodplain analysis is 261 square miles: 161 square miles of agriculture land and 99.5 acres of non-agriculture land which includes residential, commercial, industrial, and public right-of-way lands. With no project or emergency levees in place the current 10-percent chance event will impact 22 square miles of total land within the study area; of that land, 14.1 square miles is agriculture land. For the 2-percent chance event the number increases to 83.3 square miles of total land and 65.8 square miles of agriculture land. For the 1-percent chance event the number increases to 112.2 square miles of total land impacted, of which 82.4 square miles are agricultural lands. For the 0.2-percent chance event the number of acres impacted increases to 204.4 square miles out of a possible 261 square miles, of which 122.6 square miles is agricultural land (Figure 106, Figure 107, Figure 108, and Figure 109).

Figure 106 – Existing 10-percent chance event (10-year) Floodplain.

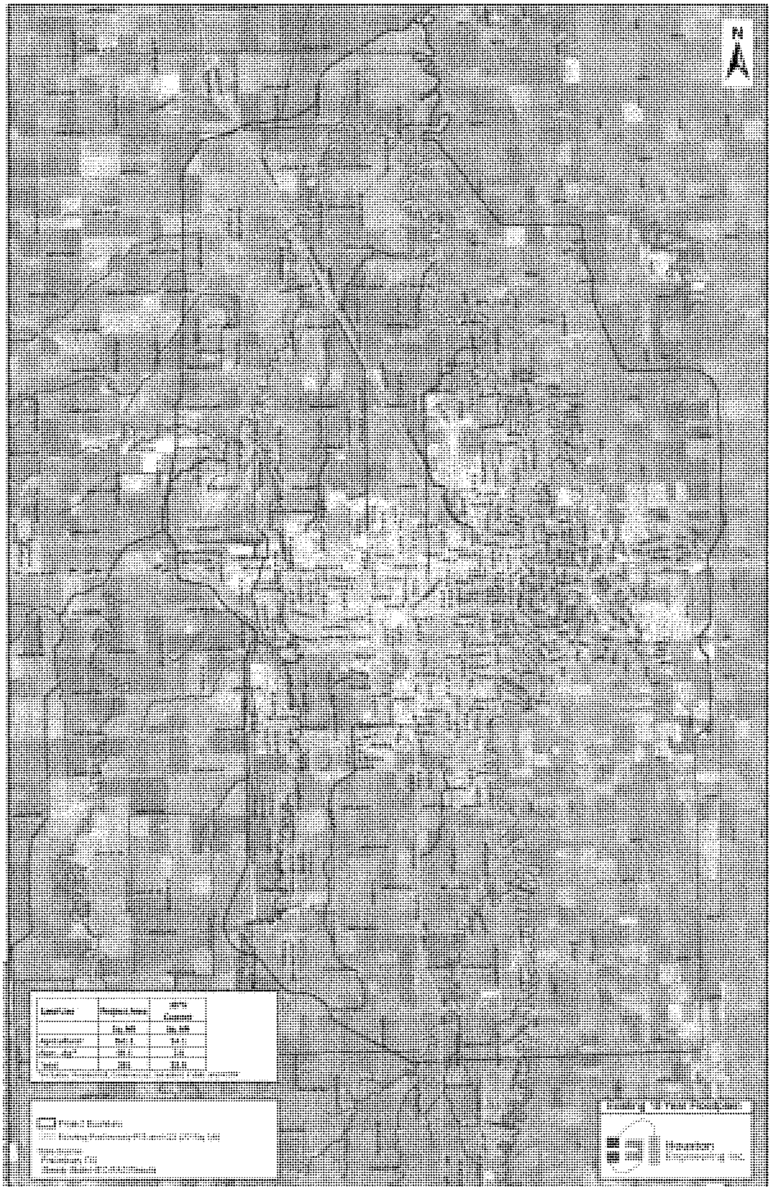


Figure 107– Existing 2-percent chance event (50-year) floodplain.

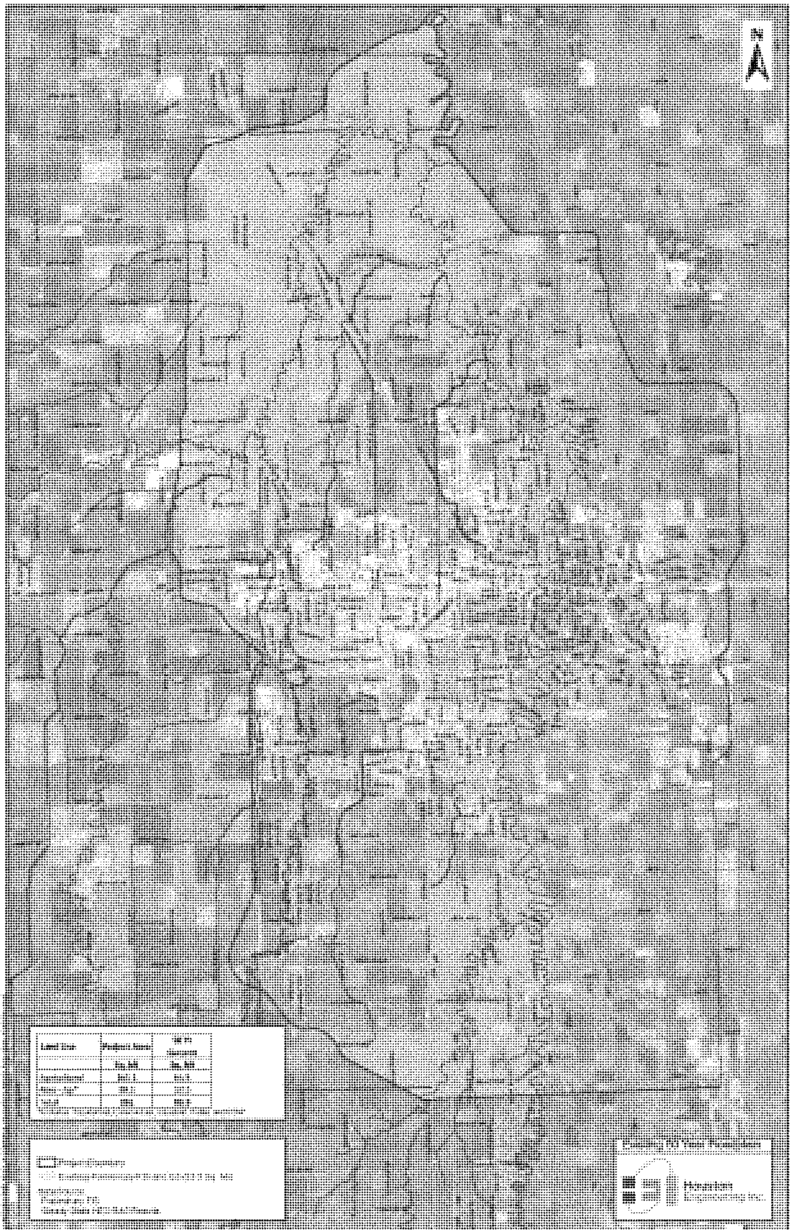
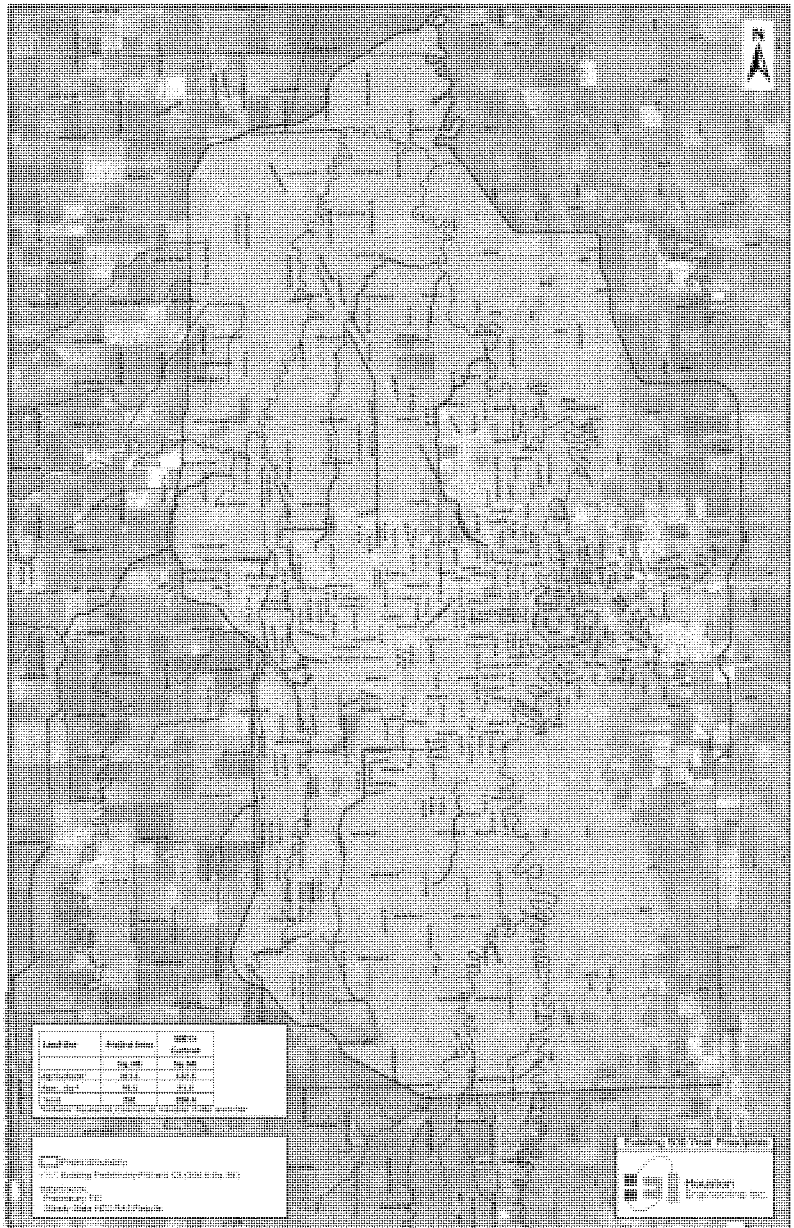


Figure 108 – Existing 1-percent chance event (100-year) floodplain

Figure 109 – Existing 0.2-percent chance event (500-year) floodplain.



A Steady State HEC-RAS hydraulic model was used to determine the impact of different size flood events within the study area. All of the diversion channel alignments will take several square miles out of the floodplain; the number of square miles will vary depending on which alternative is selected, as further discussed below.

5.2.3.2.10.2 FCP

For the FCP the model was run for the 10-percent chance event, 2-percent chance event, 1-percent chance event and 0.2-percent chance event (see Table 54). The results for the 10-percent chance event show 2.3 square miles would be taken out of the floodplain, of which 1.5 square miles are agricultural lands. The results for the 2-percent chance event show 16.5 square miles will be taken out of the floodplain, with 12.3 square miles of this being agriculture lands. The results for the 1-percent chance event show 31.3 square miles will be taken out of the floodplain, with 18.6 square miles of this being agriculture lands. The results for the 0.2-percent chance event show 80.5 square miles will be taken out of the floodplain, with 33.1 square miles of this being agriculture lands (Figure 110, Figure 111, Figure 112, and Figure 113). For the figures, the blue shading indicates inundation for existing conditions, and the pink shading indicates inundation with the project in place.

Table 54 – Floodplain impacts with project

	Total Area Removed from Floodplain (in square miles)			
Diversion Alternatives	10% Event	2% Event	1% Event	0.20% Event
LPP	1.1	45.4	69.8	87.4
FCP	2.3	16.5	31.3	80.5
ND35K	10.8	60.0	81.5	146.0

Figure 110 - FCP alignment 10-percent chance event (10-year) floodplain

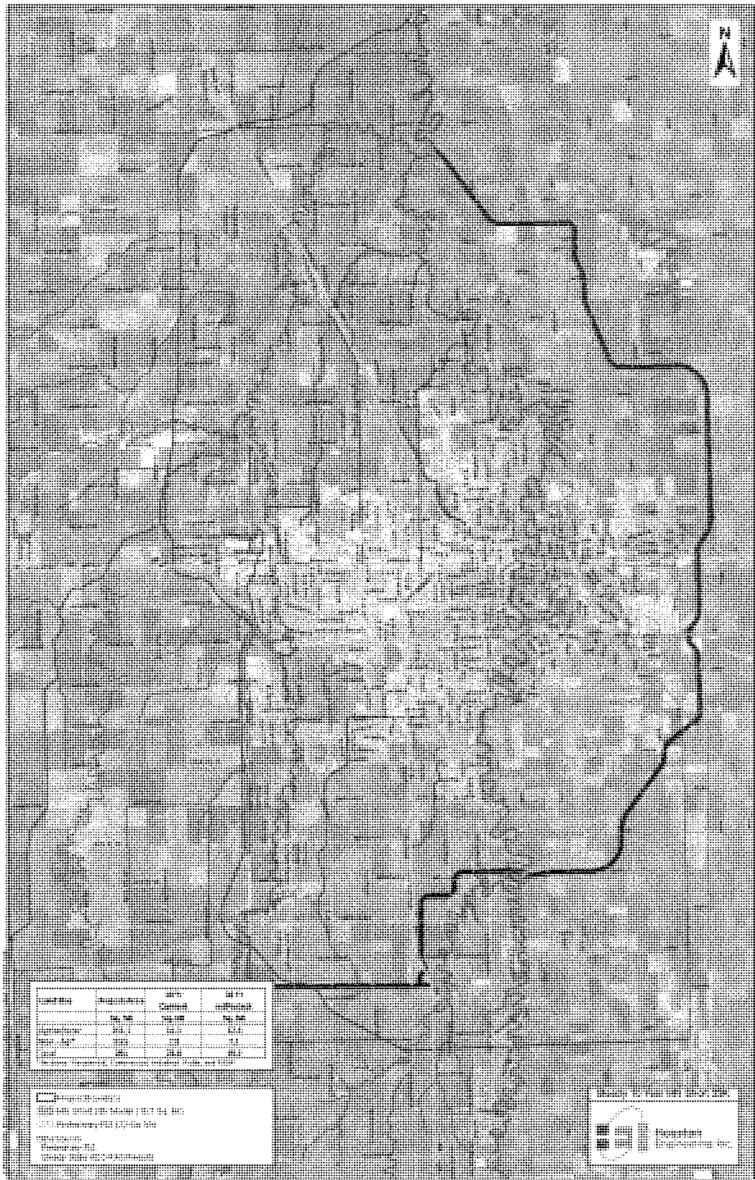


Figure 111 - FCP alignment 2-percent chance event (50-year) floodplain

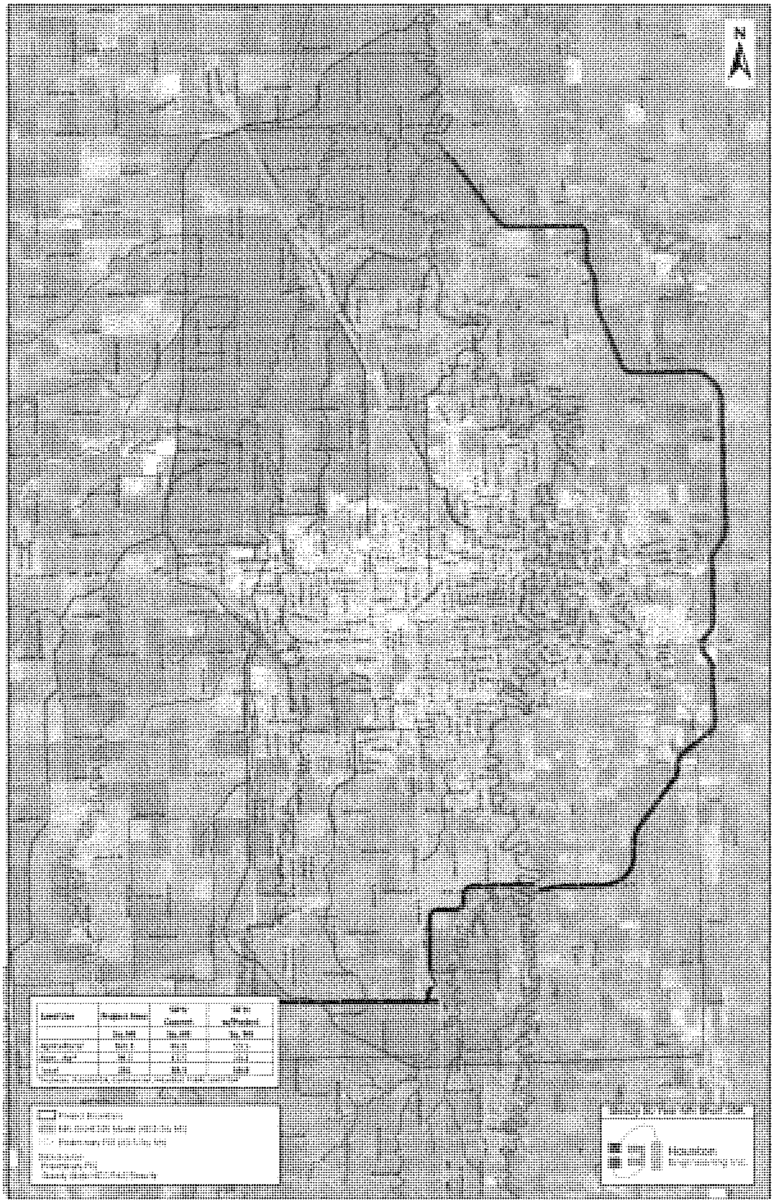


Figure 112 - FCP alignment 1-percent chance event (100-year) floodplain

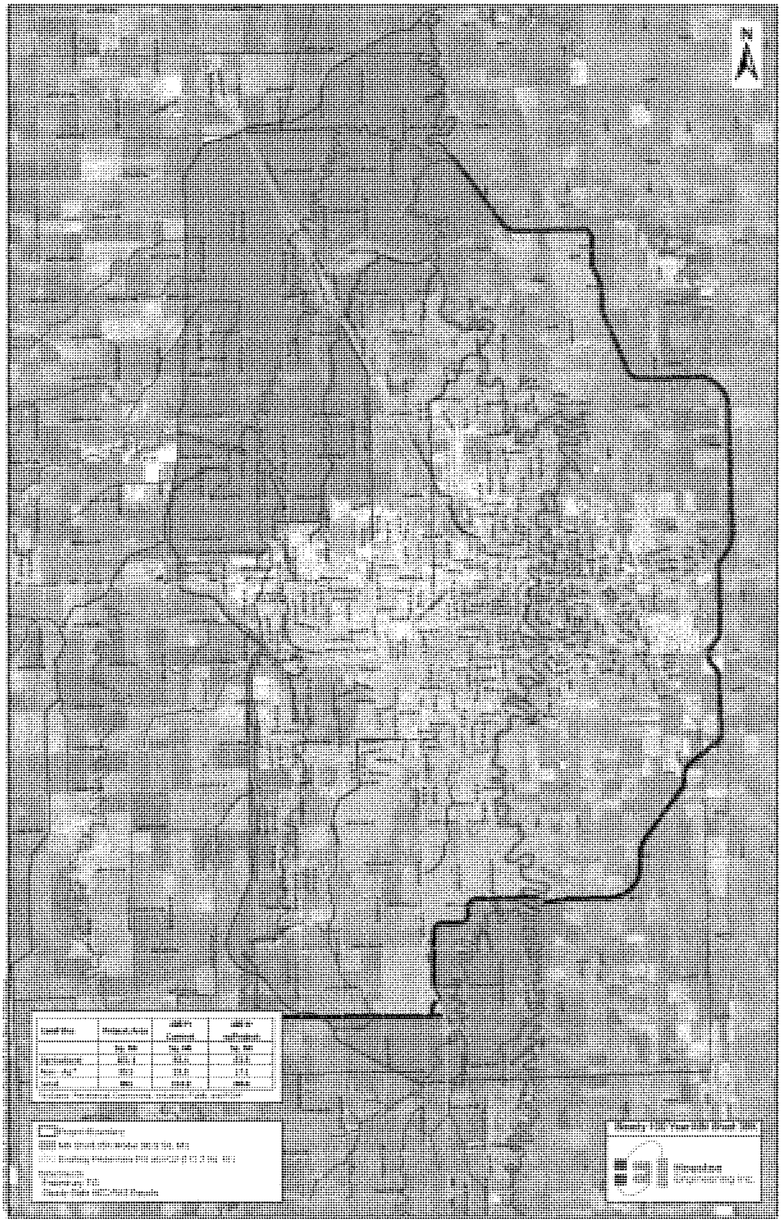
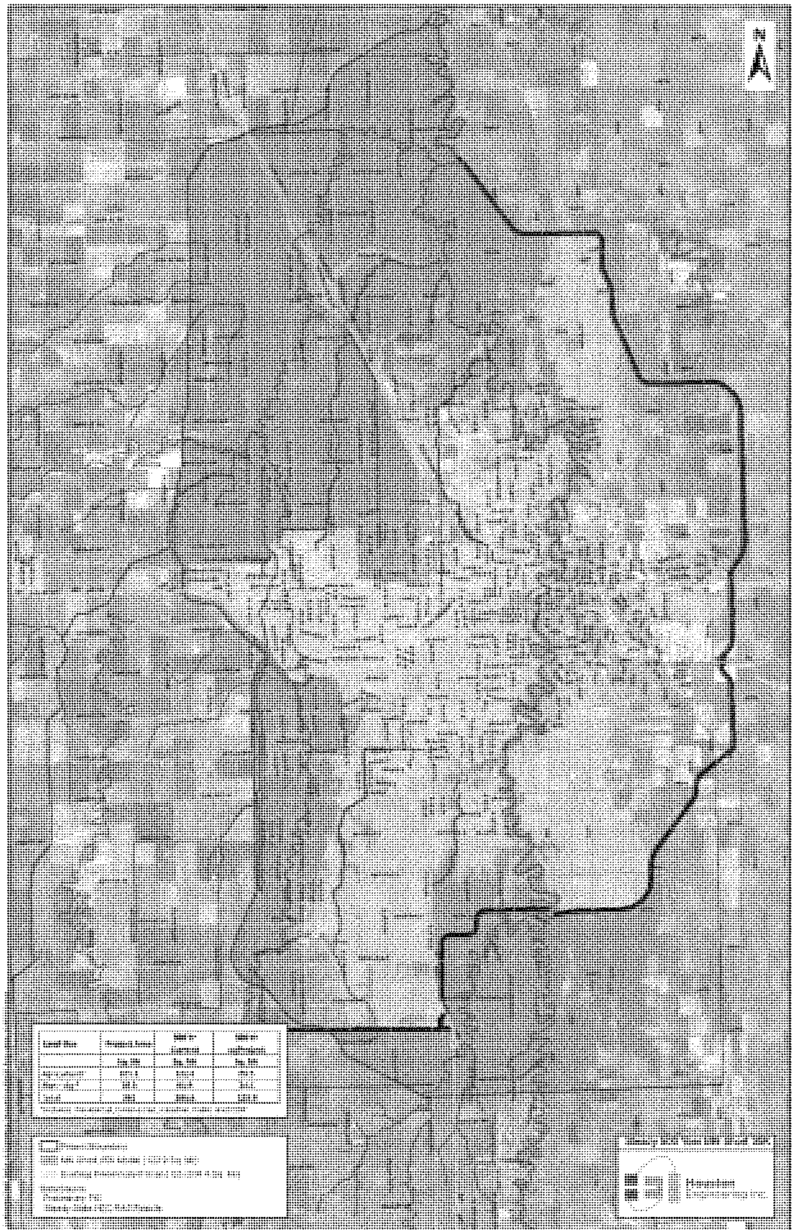


Figure 113 - FCP alignment 0.2-percent chance event (500-year) floodplain



5.2.3.2.10.3 North Dakota Alternatives
The ND35K and the LPP looked at in detail for this analysis.

5.2.3.2.10.3.1 ND35K plan
For ND35K the model was run for the 10-percent chance event, 2-percent chance event, 1-percent chance event and 0.2-percent chance event (see Table 54). The results for the 10-percent chance event show 10.8 square miles would be taken out of the floodplain, of which 8.4 square miles are agricultural lands. The results for the 2-percent chance event show 60.0 square miles will be taken out of the floodplain, with 49 square miles of this being agriculture lands. The results for the 1-percent chance event show 81.5 square miles will be taken out of the floodplain, with 59.6 square miles of this being agriculture lands. The results for the 0.2-percent chance event show 146.0 square miles will be taken out of the floodplain, with 77.3 square miles of this being agriculture lands (Figure 114, Figure 115, Figure 116, and Figure 117). For the figures, the blue shading indicates inundation for existing conditions, and the yellow shading indicates inundation with the project in place.

Figure 114 – ND35K 10-percent chance event (10-year) floodplain

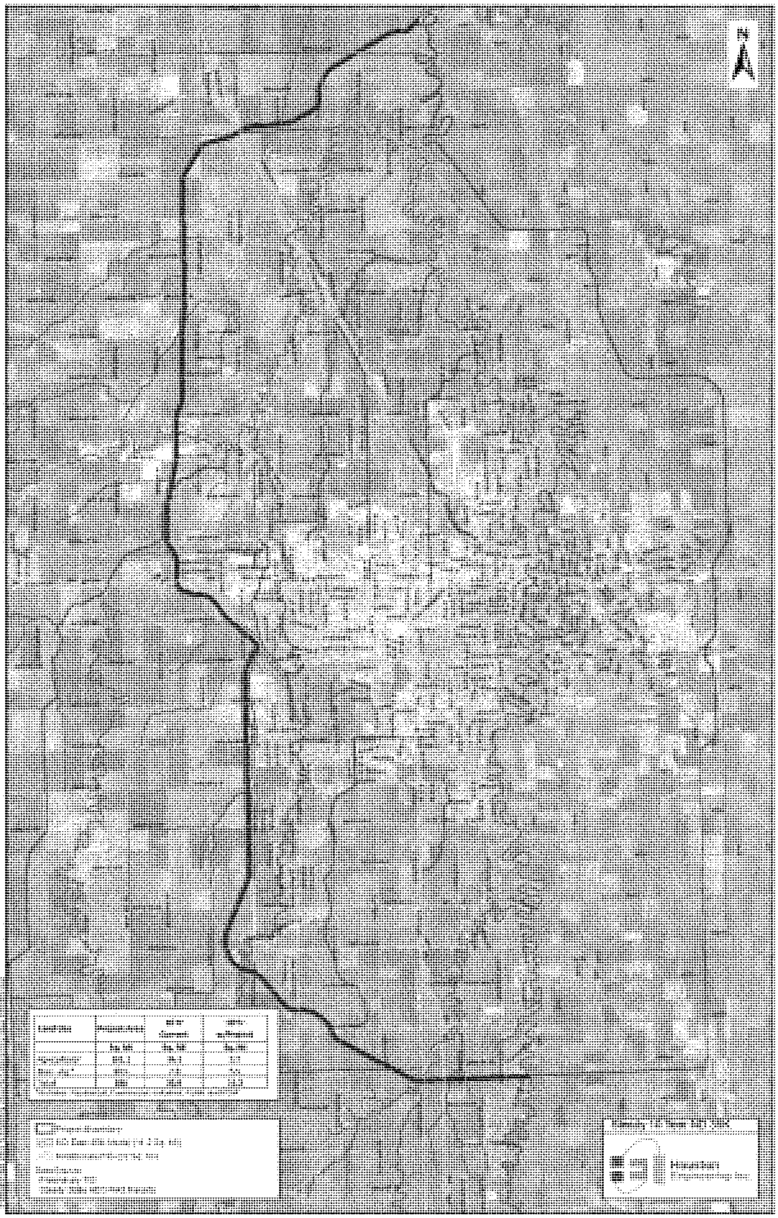


Figure 115 - ND35K 2-percent chance event (50-year) floodplain

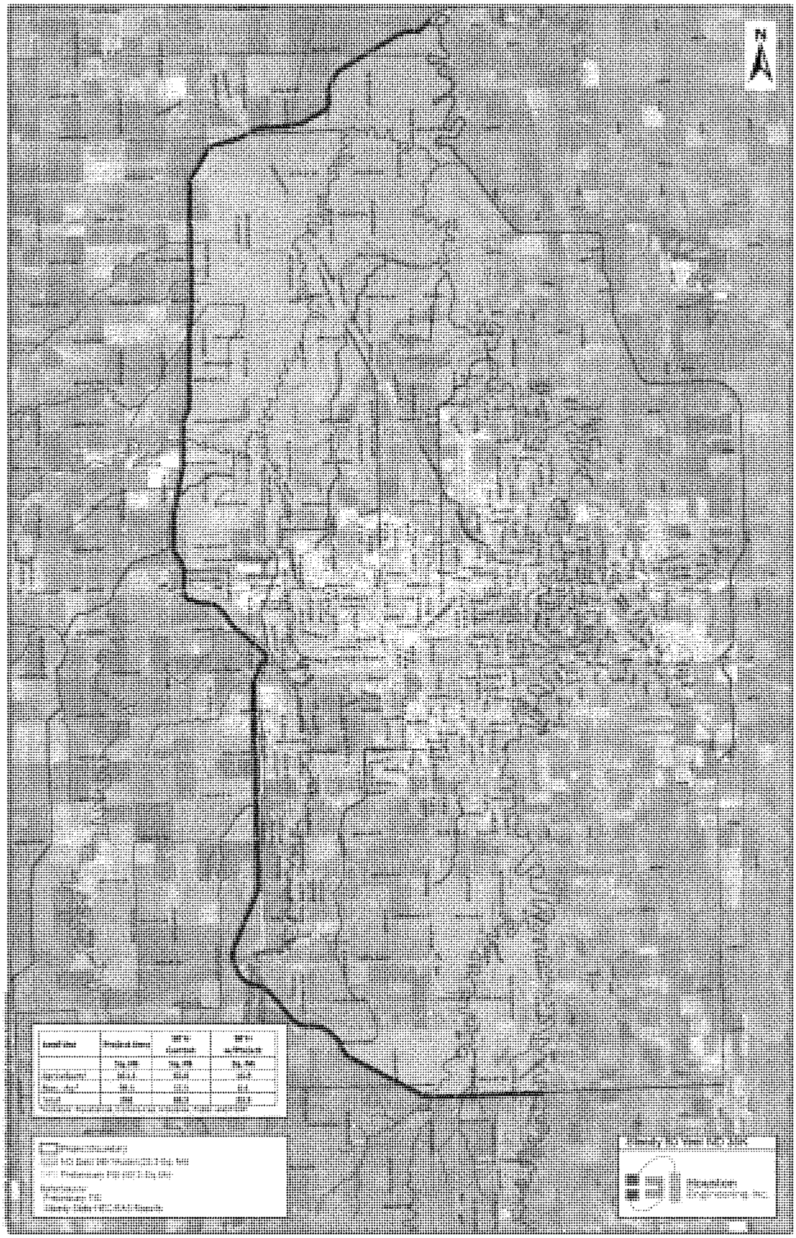


Figure 116- ND35K 1-percent chance event (100-year) floodplain

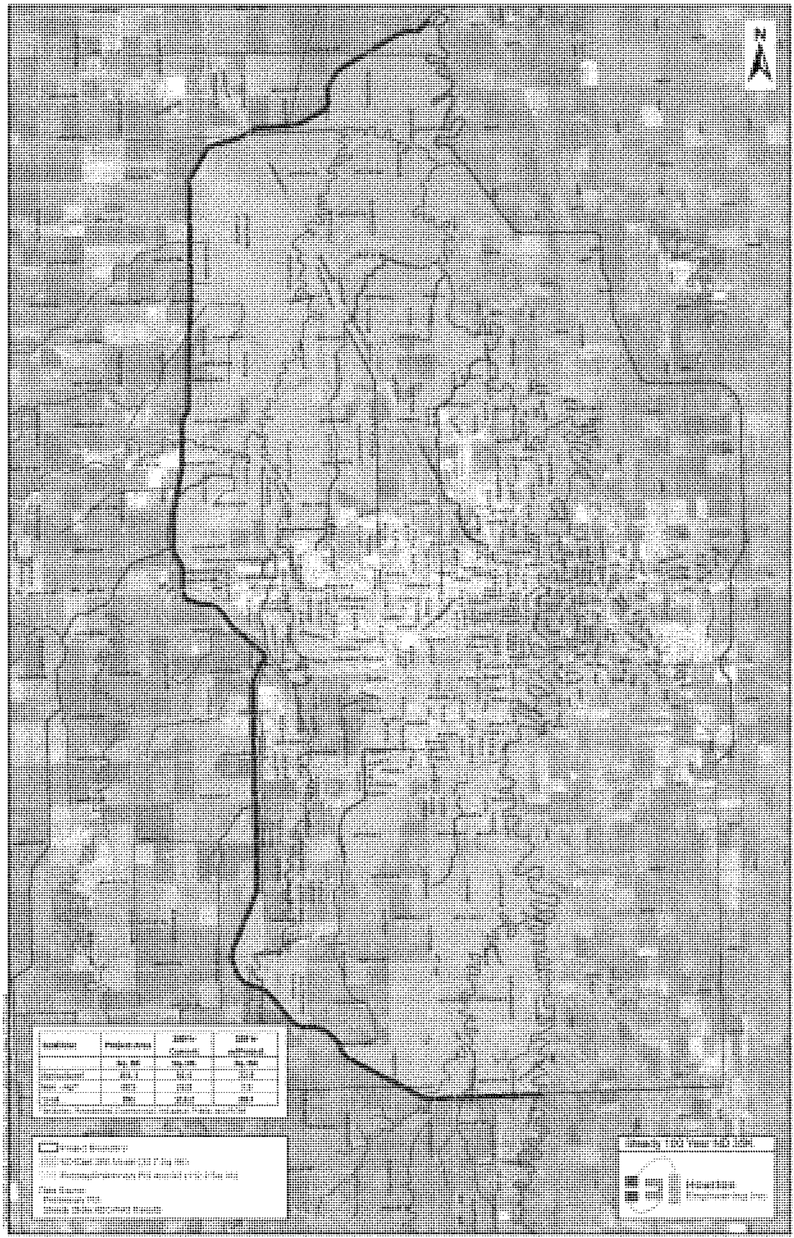
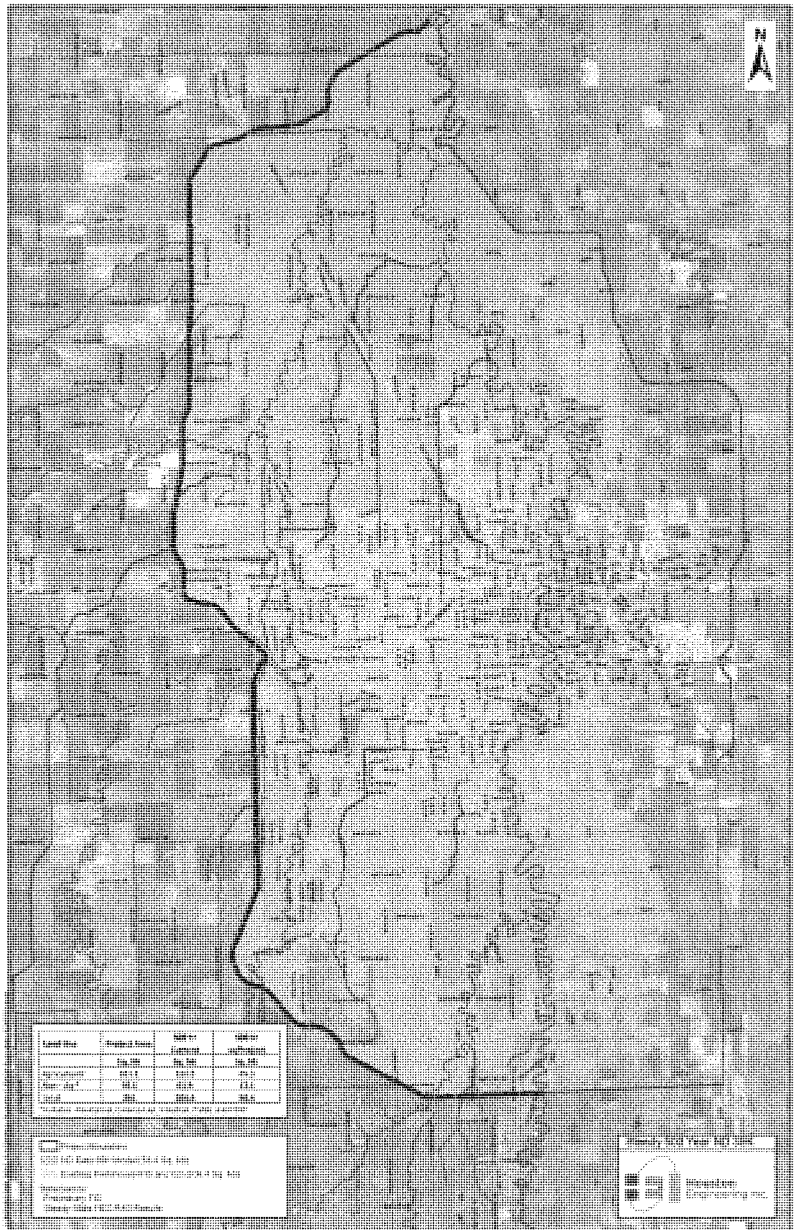


Figure 117 - ND35K 0.2-percent chance event (500-year) floodplain



5.2.3.2.10.3.2 LPP

For the LPP the model was run for the 10-percent chance event, 2-percent chance event, 1-percent chance event and 0.2-percent chance event (see Table 54). The results for the 10-percent chance event show 1.1 square miles would be taken out of the floodplain. The results for the 2-percent chance event show 45.4 square miles will be taken out of the floodplain, with 37.9 square miles of this being agriculture lands. The results for the 1-percent chance event show 69.8 square miles will be taken out of the floodplain, with 50 square miles of this being agriculture lands. The results for the 0.2-percent chance event show 87.4 square miles will be taken out of the floodplain, with 44 square miles of this being agriculture lands (Figure 118, Figure 119, Figure 120, and Figure 121). For the figures, the blue shading indicates inundation for existing conditions, and the yellow shading indicates inundation with the project in place. Although the LPP removes additional areas from the floodplain compared to the FCP, it also addresses flooding from additional tributaries, which was a concern of the non-federal sponsors. Impacts to the floodplain from the LPP have been minimized by way of the alignment and inclusion of the storage area. Furthermore, development will generally be prohibited in portions the staging area where the flood depths will be greater than three feet at the 1-percent chance event, further minimizing the impact to the floodplain.

Figure 118 – LPP 10-percent chance event (10-year) floodplain

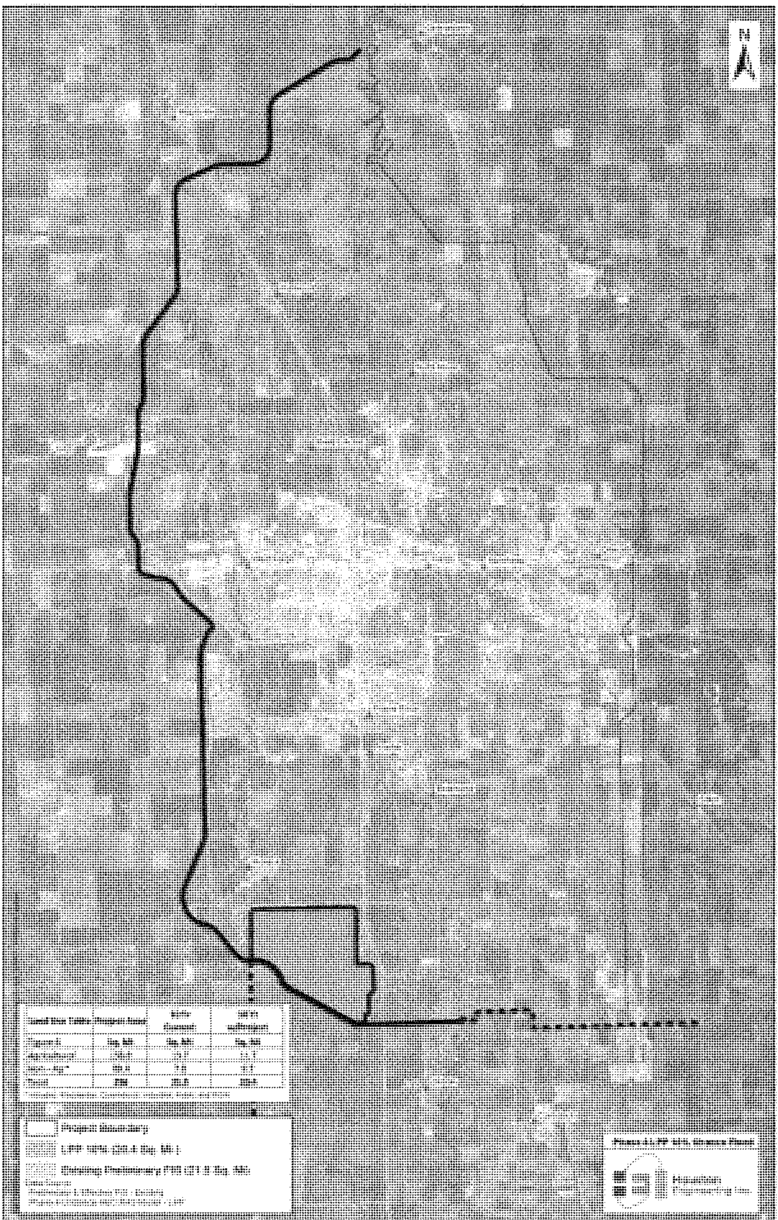


Figure 119 – LPP 2-percent chance event (50-year) floodplain

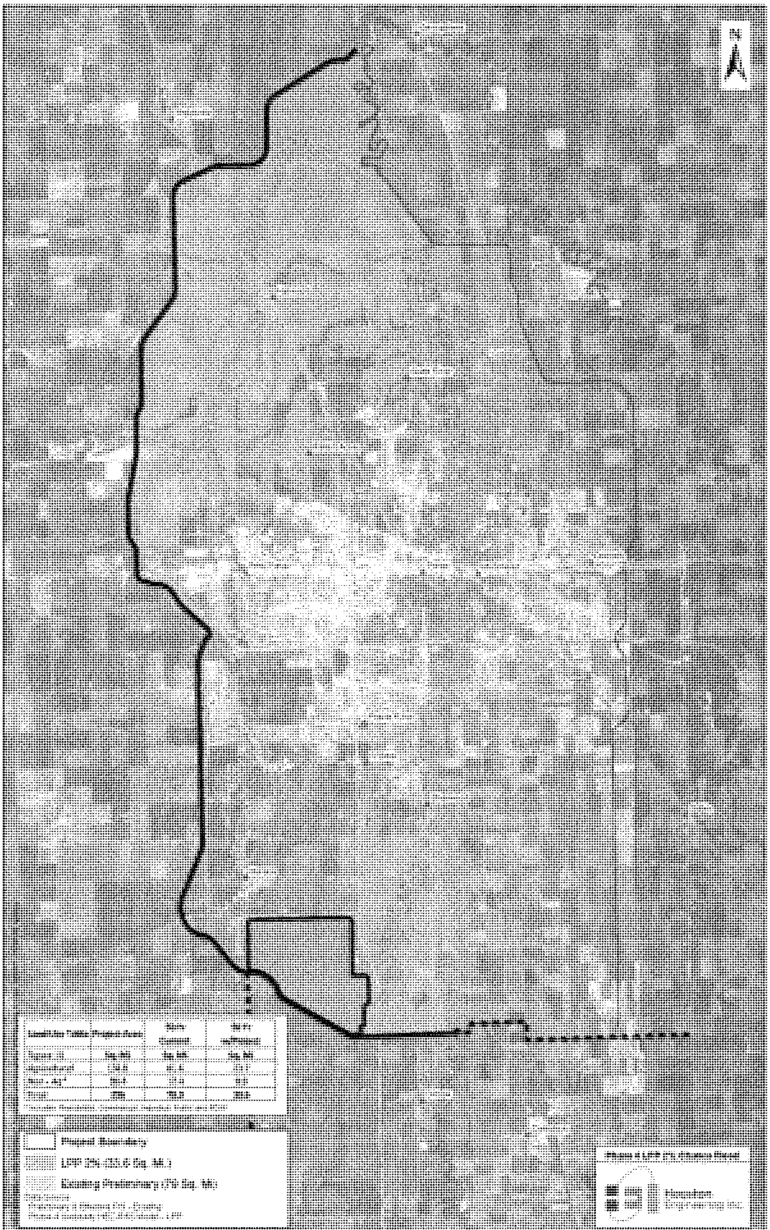


Figure 120 – LPP 1-percent chance event (100-year) floodplain

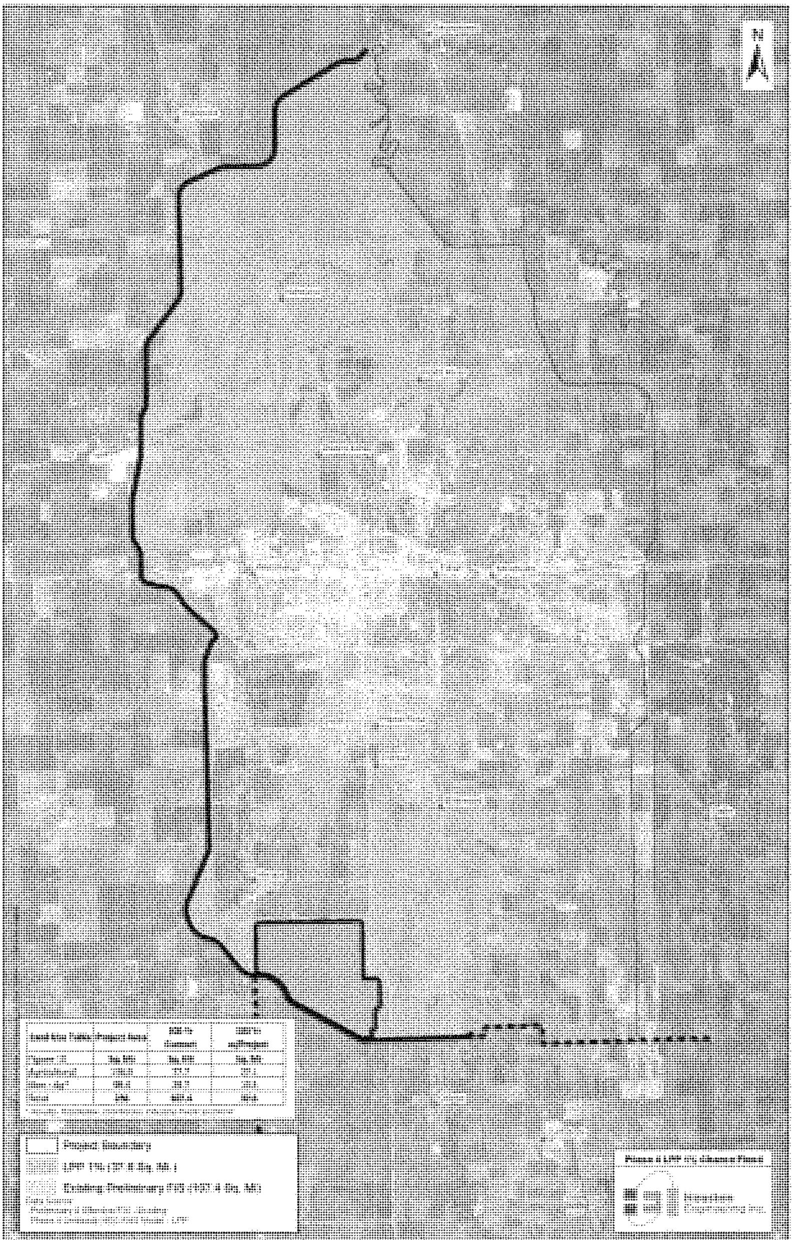
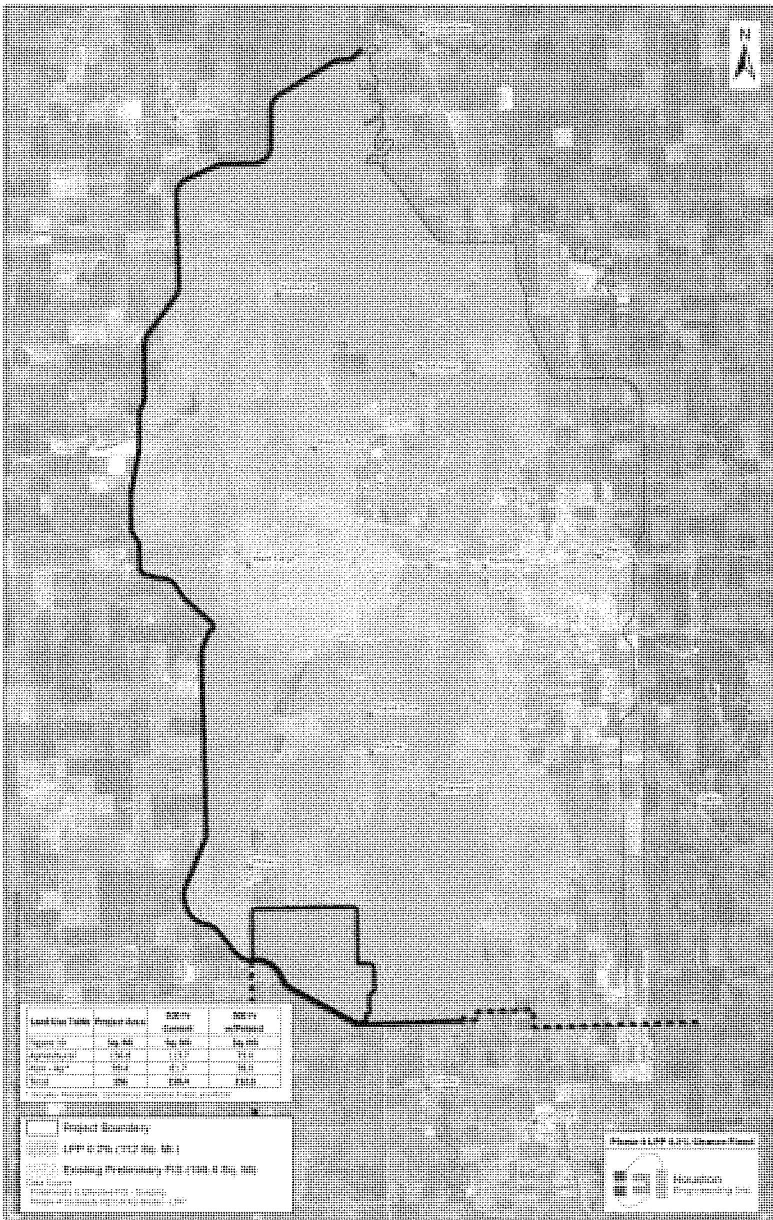


Figure 121 – LPP 0.2-percent chance event (500-year) floodplain



5.2.3.3 Environmental Justice

5.2.3.3.1 Introduction

The purpose of this environmental justice (EJ) review is to determine if a disproportionate number of low-income and minority persons would be adversely affected by the diversion channel alternatives.

5.2.3.3.2 Applicable Rules/Guidelines

Because the Corps is a part of the federal government, it must comply with Title VI of the Civil Rights Act, 42 U.S.C., Sec. 2000 et seq. This law states that "No person in the United States shall, on the ground of race, color or national origin be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance." The importance of considering EJ issues in federal actions was elevated with the February 11, 1994, signing of Executive Order (EO) 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations." EO 12898 requires that "…each Federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies and activities on minority populations and low-income populations…." [Subsection 1-101].

The EO also requires that each federal agency:

Conducts its programs, policies and activities that substantially affect human health or the environment in a manner that ensures that such programs, policies and activities do not have the effect of excluding persons and populations from participation in, denying persons and populations the benefits of, or subjecting persons or populations to discrimination under such programs, policies and activities because of their race, color or national origin [Subsection 2-2].

and

Works to ensure that public documents, notices, and hearings relating to human health or the environment are concise, understandable, and readily accessible to the public [Subsection 5-5(c)].

5.2.3.3.3 Identification of Minority and Low-Income Populations

This section presents an evaluation of the demographic composition of the population in the study area. The study area extends from the Canadian border along the Red River to Abercrombie, ND, and includes portions of six counties in North Dakota and six in Minnesota. The North Dakota counties, from north to south, are Pembina, Walsh, Grand Forks, Traill, Cass, and Richland Counties. The Minnesota counties, from north to south, are Kittson, Marshall, Polk, Norman, Clay, and Wilkin Counties. The demographic composition of these 12 counties is compiled as part of the analysis. As race and income related data at the census block and census block group level is not yet available from the 2010 U.S Census for these geographies, data from the 2000 U.S Census has been utilized. Race characteristics at the census block level and income characteristics at the block group level from the 2000 U.S. Census of Population and Housing were analyzed to identify populations of concern with respect to potential EJ issues. Detailed information at the block and block group levels are computed based on the decennial census, which are determined between census periods. The following information was collected for specific blocks and block groups and aggregated to represent the study area:

- Racial and Ethnic Characteristics – race and ethnic populations in each census block of the study area were characterized using the following racial categories: Hispanic White (for which demographic data is reported as one category by the U.S. Census), Black or African American, American Indian and Alaska Native, Asian, Native Hawaiian and Other Pacific Islander, Persons of Hispanic Origin, and Other. These categories are consistent with the affected populations requiring study under EO 12898.
- Percentage of Minority Population – As defined by the U.S. Census Bureau, the minority population includes all non-Whites and White-Hispanic persons. According to Council of Environmental Quality guidelines, "Minority populations should be identified where either: (a) the minority population of the affected area exceeds 50 percent or (b) the minority population percentage of the affected area is meaningfully greater than the minority population percentage in the general population or other appropriate unit of geographic analysis."
- Low-Income Population – The percentage of persons living below the poverty level, as defined in the 2000 U.S. Census, was one of the indicators used to determine the low-income population in a given census block or tract. The median household income and per capita income were also used to characterize income levels.

Population characteristics of the 12 counties are used to define the reference population for comparative purposes throughout this analysis. Table 55 and Table 56 show minority and low-income population characteristics in the North Dakota and Minnesota counties.

Table 55 - Population and Economic Characteristics of Study Areas – North Dakota

Race	**North Dakota**											
	Pembina County		**Walsh County**		**Grand Forks County**		**Traill County**		**Cass County**		**Richland County**	
	Number	**%**	**Number**	**%**	**Number**	**%**	**Number**	**%**	**Number**	**%**	**Number**	**%**
White	8,198	95.5%	11,752	94.9%	61,479	93.0%	8,249	97.3%	117,106	95.1%	17,428	96.8%
Non-Hispanic White	8,058	93.9%	11,436	92.3%	60,801	92.0%	8,170	96.4%	116,263	94.4%	17,337	96.3%
Hispanic White	140	1.6%	316	2.6%	678	1.0%	79	0.9%	843	0.7%	91	0.5%
Non-White	387	4.5%	637	5.1%	4,630	7.0%	228	2.7%	6,032	4.9%	570	3.2%
Black or African American alone	13	0.2%	41	0.3%	904	1.4%	9	0.1%	996	0.8%	62	0.3%
American Indian and Alaska Native alone	123	1.4%	126	1.0%	1,525	2.3%	80	0.9%	1,325	1.1%	299	1.7%
Asian alone	18	0.2%	24	0.2%	646	1.0%	13	0.2%	1,551	1.3%	44	0.2%
Native Hawaiian and Other Pacific Islander alone	-	0.0%	2	0.0%	44	0.1%	1	0.0%	43	0.0%	6	0.0%
Some other race alone	109	1.3%	311	2.5%	475	0.7%	81	1.0%	530	0.4%	25	0.1%
Two or more races	124	1.4%	133	1.1%	1,036	1.6%	44	0.5%	1,587	1.3%	134	0.7%
Total	8,585	100.0%	12,389	100.0%	66,109	100.0%	8,477	100.0%	123,138	100.0%	17,998	100.0%
Minority Population	527	6.1%	953	7.7%	5,308	8.0%	307	3.6%	6,875	5.6%	661	3.7%
Persons Below Poverty		9.2%		10.9%		12.3%		9.2%		10.1%		10.4%
Per-Capita Income	$18,692		$16,496		$17,868		$18,014		$20,889		$16,339	
Median Household Income	$36,430		$33,845		$35,785		$37,445		$38,147		$36,098	

Source: U.S. Department of Commerce, U.S. Census Bureau, 2000. SF1 and SF3 Tables

Table 56 - Population and Economic Characteristics of Study Areas–Minnesota

Race	Minnesota											
	Kittson County		Marshall County		Polk County		Norman County		Clay County		Wilkin County	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
White	5,184	98.1%	9,873	97.2%	29,543	94.2%	7,092	95.3%	48,149	94.0%	6,979	97.8%
Non-Hispanic White	5,142	97.3%	9,750	96.0%	28,994	92.4%	6,957	93.5%	47,330	92.4%	6,912	96.8%
Hispanic White	42	0.8%	123	1.2%	549	1.8%	135	1.8%	819	1.6%	67	0.9%
Non-White	101	1.9%	282	2.8%	1,826	5.8%	350	4.7%	3,080	6.0%	159	2.2%
Black or African American alone	8	0.2%	10	0.1%	104	0.3%	8	0.1%	268	0.5%	11	0.2%
American Indian and Alaska Native alone	14	0.3%	29	0.3%	408	1.3%	129	1.7%	740	1.4%	30	0.4%
Asian alone	13	0.2%	17	0.2%	95	0.3%	23	0.3%	449	0.9%	11	0.2%
Native Hawaiian and Other Pacific Islander alone	-	0.0%	-	0.0%	5	0.0%	-	0.0%	14	0.0%	1	0.0%
Some other race alone	20	0.4%	165	1.6%	806	2.6%	84	1.1%	857	1.7%	35	0.5%
Two or more races	46	0.9%	61	0.6%	408	1.3%	106	1.4%	752	1.5%	71	1.0%
Total	5,285	100.0%	10,155	100.0%	31,369	100.0%	7,442	100.0%	51,229	100.0%	7,138	100.0%
Minority Population	143	2.7%	405	4.0%	2,375	7.6%	485	6.5%	3,899	7.6%	226	3.2%
Persons Below Poverty		10.2%		9.8%		10.9%		10.3%		13.2%		8.1%
Per-Capita Income	$16,525		$16,317		$17,279		$15,895		$17,557		$16,873	
Median Household Income	$32,515		$34,804		$35,015		$32,535		$37,889		$38,093	

Source: U.S. Department of Commerce, U.S. Census Bureau, 2000. SF1 and SF3 Tables.

For comparative purposes at the county level, with the exception of Clay County, MN and Polk County, MN, and Grand Forks and Cass Counties, ND, all the other counties in the study area experienced a decline in population between 2000 and 2010. The decreases ranged from 4.4 percent to as much as 16.1 percent.

5.2.3.3.4 Minority Analyses

To better understand the location of minority persons in the counties in the study area, percentages of minority persons by census block were calculated and mapped. As shown in Figure 122, Figure 124, Figure 126, Figure 128, Figure 130, and Figure 132 there are very few census blocks with minority persons along the Red River in both states that exceed the state threshold of minority persons.

As shown in Table 55, the percentage of minority persons in the North Dakota counties is highest in Grand Forks County (8.0 percent). Traill County reported the lowest percentage of minority persons, with 3.6 percent. In the Minnesota counties, Polk and Clay Counties reported the highest percentage of minority persons, with 7.6 percent each. Kittson County reported the lowest percentage of minority persons (2.7 percent).

The proposed diversion channels run through portions of Cass County, ND, and Clay County, MN. In Cass County, minority persons account for 5.6 percent of the total population (U.S. Census Bureau, 2000). Greater concentrations of minority persons were identified south of I-94 and in areas near the intersection of I-94 and I-29. As shown in Figure 130, the North Dakota diversion alignment does not appear to intersect any census blocks that have higher concentrations of minority persons than the Cass County threshold of 5.6 percent. As shown in Table 56, minority persons in Clay County, MN, account for 7.6 percent of the total population. Small pockets of minority persons are spread throughout the city of Moorhead and in the eastern portion of the city of Dilworth. Pockets of minority persons are also located toward the northern and southern portions of the County. Just four census blocks along the FCP alignment were identified with higher concentrations of minority persons than the Clay County threshold of 7.6 percent. The minority population in these blocks ranges from one to four persons.

5.2.3.3.5 Poverty and Income Analyses

In the North Dakota counties, Grand Forks County reported the highest percentage of persons living below the poverty level, with 12.3 percent and is the only North Dakota county that reported levels of poverty exceeding the State threshold of 11.9 percent. Compared to the State's median household income of $34,604, five of the six North Dakota counties have higher median household incomes. Four of the counties have higher per capita incomes than the State average of $17,769. Overall, residents of the study area in North Dakota counties are better off as measured by income and poverty.

All of the six Minnesota counties have higher levels of poverty than the State threshold of 7.9 percent. None of the Minnesota counties have higher per capita incomes than the State average of $23,198 or higher median household incomes than the State median of $47,111 (U.S Census Bureau, 2000)

In Clay County, MN, and Cass County, ND, through which the diversion channels run, the percentage of persons living below the poverty level is 13.2 percent and 10.1 percent of the total population, respectively. Figure 133 shows the locations of block groups with a higher percentage of persons living below the poverty level than the county thresholds. In both counties, higher percentages of persons living below the poverty level appear to be present in urban areas that are not immediately adjacent to the diversion channel locations. The alignments do not intersect any census block groups with higher percentages of persons living below the poverty level than the county thresholds.

5.2.3.3.6 Determination of Disproportionately High and Adverse Effects on Populations of Concern

The determination of whether the populations of concern would be subject to disproportionately high and adverse environmental impacts involves two principal considerations: evidence of previous disproportionate environmental degradation caused by past major projects or pre-existing sources of environmental contamination, and a disproportionate distribution of impacts caused by the alternatives. The first consideration involves projects or impacts that occurred in the past and may still be affecting these populations of concern. One of the purposes of EO 12898 is to ensure that areas of high minority and low-income concentrations have not previously been "dumping grounds" for land uses that cause substantial adverse environmental impacts. The second consideration involves determining whether plans for the alternatives have been directed toward areas of high minority and low-income concentrations due to factors such as lower property values or expectations of less effective citizen opposition.

The following types of impacts were evaluated for this analysis:

- Previous Environmental Degradation—Previous degradation to the physical or social environment in a minority or low-income community can arise from past projects that had major impacts or an accumulation of land uses that have a negative impact on the environment. Additional impacts related to the alternatives, however small, can have a greater cumulative effect in areas where previous levels of degradation are high.
- Impacts Related to the Diversion Channel Alternatives—Impacts identified in this and other technical studies have been evaluated to determine whether their effect is borne disproportionately by populations of concern. Issues considered include:

- Induced flooding affecting low-income and minority persons
- Residential and business displacement due to right-of-way (ROW) acquisition
- Changes in accessibility and mobility caused by the diversion channel alternatives
- Noise

The U.S. Environmental Protection Agency (EPA) maintains a detailed database of point sources of environmental contaminants.[1] This database is a good indicator of the degree of pre-existing environmental degradation throughout the country. EPA-regulated site data is provided by zip code area and street address. Emphasis was placed on identifying projects that required environmental reviews under the National Environmental Policy Act, and major local or State construction projects (e.g., solid waste disposal facilities, incinerators, trash disposal or transfer facilities, major transportation projects). Major private projects were not considered unless they involved significant environmental effects, in which case they probably would have required environmental reviews. The analysis found that, other than establishments that handle hazardous wastes, no environmentally sensitive establishments, such as active or archived Superfund sites, are located in the study area[2].

5.2.3.3.7 Environmental Justice Conclusions

Currently, three diversion channel alternatives are being analyzed as part of the Feasibility Study. Long-term impacts from the diversion channels would include induced flooding and loss of farmland due to land acquisition. Based on hydrology and hydraulics studies, there would be some areas that could experience induced flooding for all of the diversion channel alternatives. Areas where the induced flooding at the 1-percent chance event would exceed 1 foot were mapped by alternative. The locations of minority and low-income concentrations were then overlain on the areas with the potential increased flooding to illustrate the location of impacts in relation to the populations of concern.

For the FCP, areas in Clay, Norman, and Polk Counties, MN, would experience some induced flooding in excess of 1 foot (see Figure 122-Figure 127). However, areas of flooding do not appear to be concentrated in the minority and low-income areas in these counties.

For the ND35K, there would be some induced downstream flooding at the 1-percent chance event in excess of 1 foot in Traill and Cass Counties, ND (see Figure 128-Figure 133). However, the increased flooding does not appear to be concentrated in the minority and low-income areas in these counties.

The LPP includes staging areas upstream of the diversion inlet with stage increases of up to 8 feet at the 1-percent chance event (see Figure 134 - Figure 137). A large part of the staging area would be purchased in fee, or have mitigation of impacts with flowage easements or ring-levees. Impacts will

1 www.epa.gov/enviro/html/cerclis/cerclis_query.html

2 A Superfund site is an uncontrolled or abaudoued place where hazardous waste is located, possibly affecting local ecosystems or people. Sites are listed on the National Priorities List (NPL), which guides the Environmental Protection Agency (EPA) in making a determination on sites that require further investigation. They are listed upon completion of a Hazard Ranking System screening, public solicitatiou of comments about the proposed site, and after all comments have been addressed. (Source: www.epa.gov/superfund/sites/index.htm).

be evaluated on a case by case basis to determine if there will be a taking. The extent of induced flooding does not appear to be concentrated in the minority and low-income areas in these counties.

One of the concerns regarding the FCP and ND35K is the increased potential for induced flooding downstream. Based on U.S Census 2010 data at the County level, the racial composition of the downstream communities closely mirrors that of the metro area; however, there is slightly less diversity downstream. The percentage of minority persons in the upstream counties of Richland County, ND and Wilkin County, MN are low and there does not appear to a concentration of minority or low-income persons along the river. Comparing the populations that are fluent in English with those that are not finds a higher share of non-English speaking persons in most of the North Dakota downstream counties compared to the city of Fargo. However, on the Minnesota side the share of non-English speakers in the downstream counties was lower than those reported in Moorhead (U.S. Census Bureau, 2010). Richland County, ND had a slightly higher proportion of Spanish speaking persons than the city of Fargo.

Education level was also considered as part of this review. Both upstream and downstream study area counties in North Dakota had higher percentage of persons with a high school diploma compared to levels exhibited in Fargo. Similarly, both the upstream and downstream counties in Minnesota had higher levels of persons with a high school diploma than was found in Moorhead. However, the percentage of persons with college and Bachelor's degrees was higher in Fargo and Moorhead compared to upstream and downstream counties in their respective states and this is primarily due to the large number of educational facilities in these two cities compared to the other jurisdictions.

There is a lower percentage of children below the age of 5 years in the population of the downstream communities, but a higher percentage of individuals 65 years old or older. Based on these findings, it can be generalized that, on average, the downstream communities have a slightly higher percentage of older individuals than is found in the metro area.

The EPA's "Toolkit for Assessing Potential Allegations of Environmental Injustice" offers a definition for disproportionately high and adverse effects or impacts as those "(1)...predominately borne by any segment of the population, including, for example, a minority population and/or a low-income population; or (2) will be suffered by a minority population and/or low-income population and is appreciably more severe or greater in magnitude than the adverse effect or impact that will be suffered by a non-minority population and/or non-low-income population."

Any downstream impacts created by the FCP or ND35K, regardless of location or extent, would not adversely affect minority or low-income populations more severely or in greater numbers than it would the wealthier, White populations. Upstream impacts due to the staging areas or flooding do not appear to disproportionately impact minority or low-income populations. In the event of downstream impacts, those with higher median household incomes or higher levels of education would be affected to the same extent as those who are not proficient in English or who are over 65 years old. This non-discriminatory nature of any upstream or downstream effects minimizes any EJ impacts; therefore, it cannot be said that these groups would bear a disproportionately high and adverse share of the effects of the FCP, ND35K, or LPP.

In addition to the acquisition of land for the project, a diversion channel would cause changes in accessibility and mobility across farms and have air quality- and noise-related impacts during construction. The diversion channel alternatives would divide farms into separate parcels. In some cases, farmers would have to detour around the diversion channel using established roadways or specially constructed access roads to access their property and conduct farming operations. The number of farms in active use that would be divided by each of the alternatives is unknown at this preliminary stage. Mitigation measures would be incorporated into the final project design to minimize impacts on farmland and commuting. Currently each diversion channel alignment has bridges approximately every 3 miles as discussed in Chapter 3.

Figure 122 - Traill County, ND and Norman County, MN: Census Blocks Showing Minority Persons and Areas of Induced Flooding with the FCP – 1-percent chance event

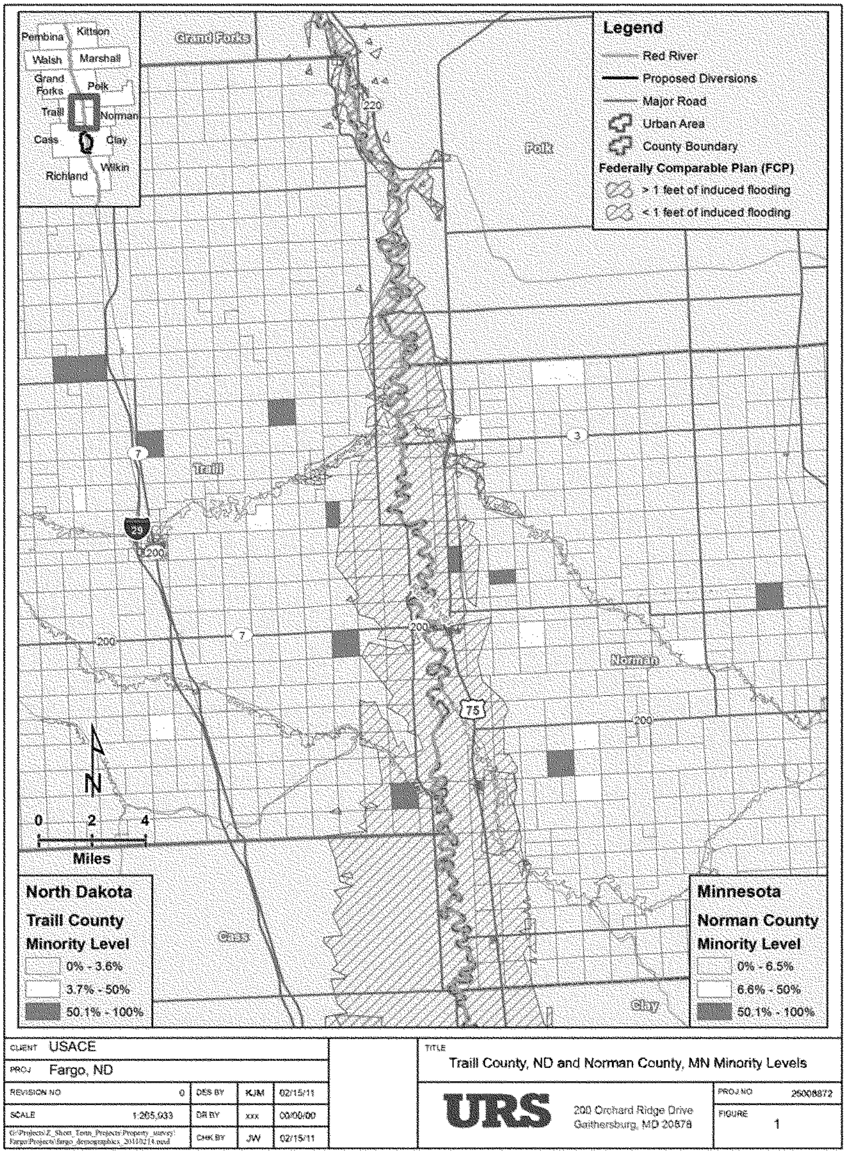


Figure 123 - Trail County, ND and Norman County, MN: Census Block Groups Showing Persons Below Poverty and Areas of Induced Flooding with the FCP– 1-percent chance event

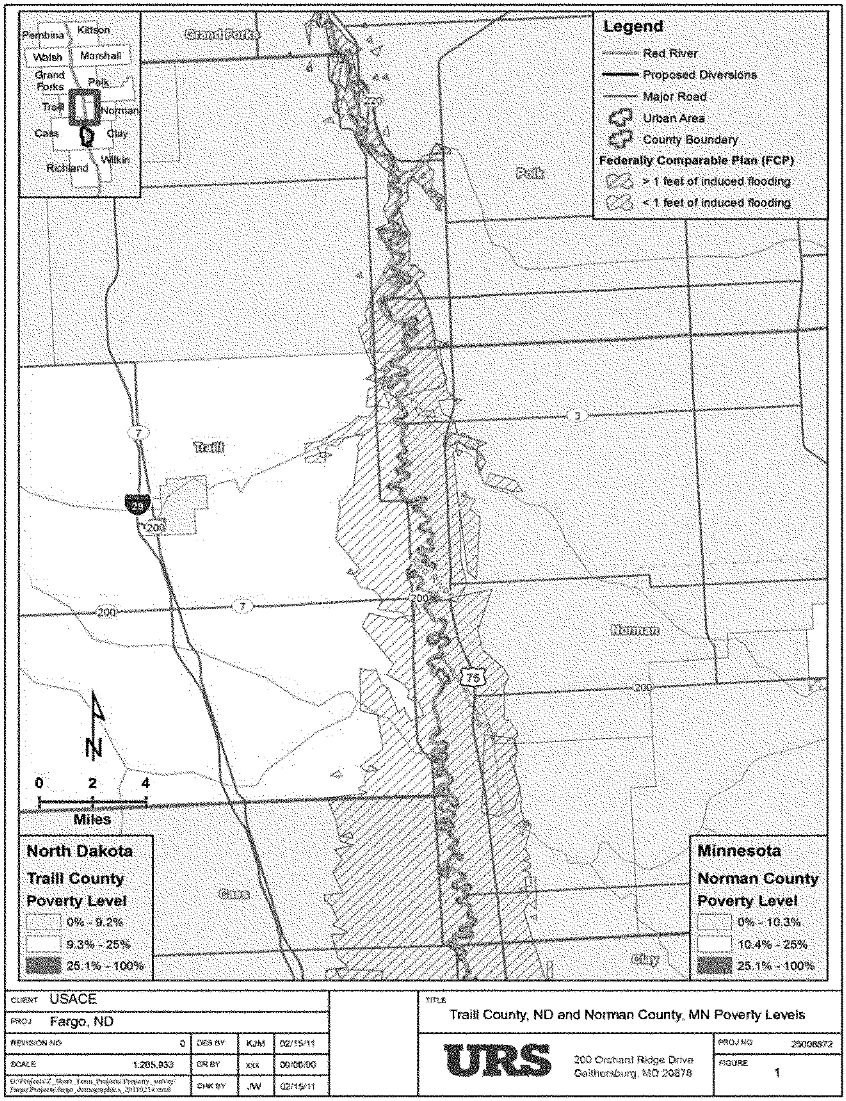


Figure 124 - Grand Forks County, ND and Polk County, MN: Census Blocks Showing Minority Persons and Areas of Induced Flooding with the FCP – 1-percent chance event

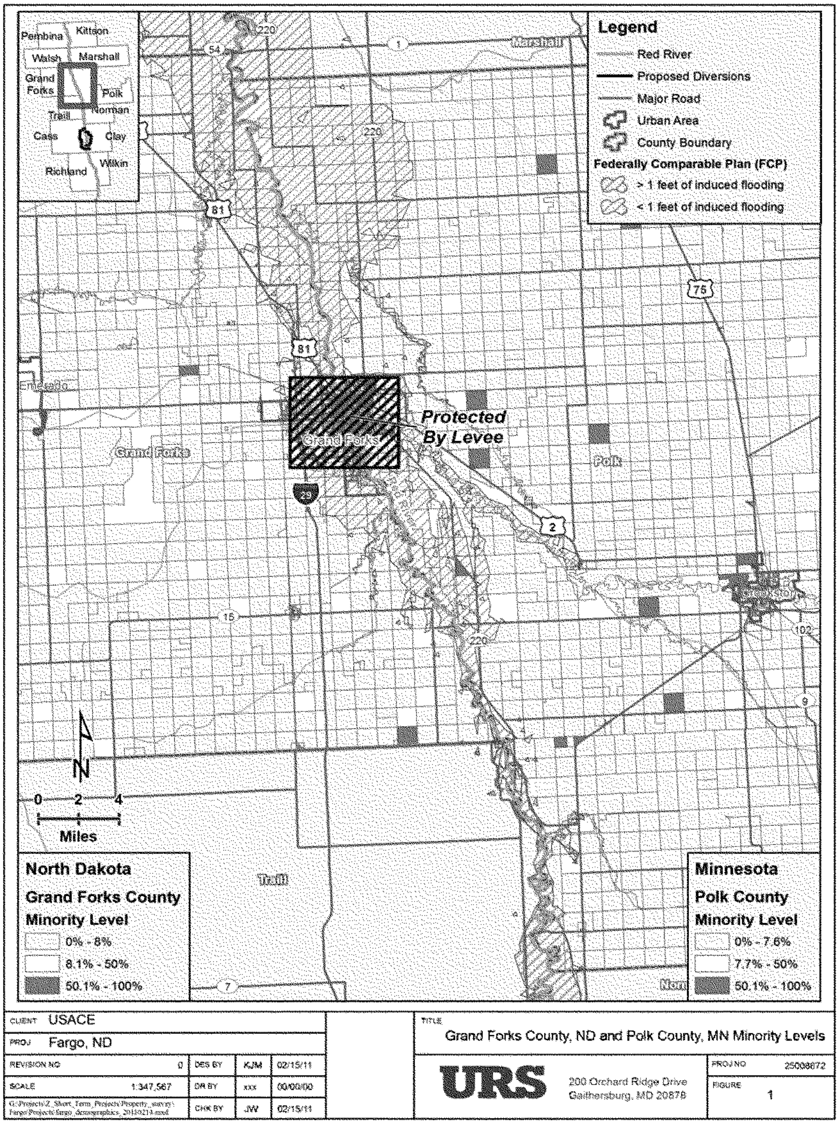


Figure 125 - Grand Forks County, ND and Polk County, MN: Census Block Groups Showing Persons Below Poverty and Areas of Induced Flooding with the FCP– 1-percent chance event

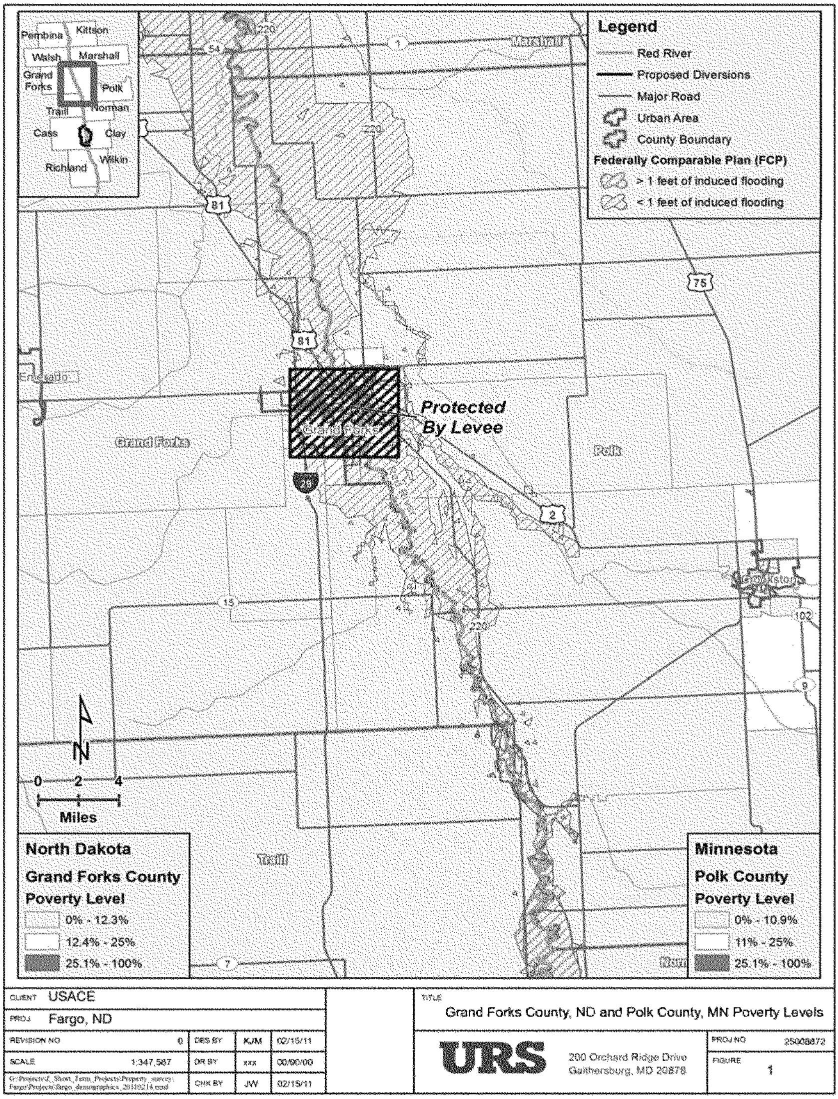


Figure 126 - Cass County, ND and Clay County, MN: Census Blocks Showing Minority Persons and Areas of Induced Flooding with the FCP – 1-percent chance event

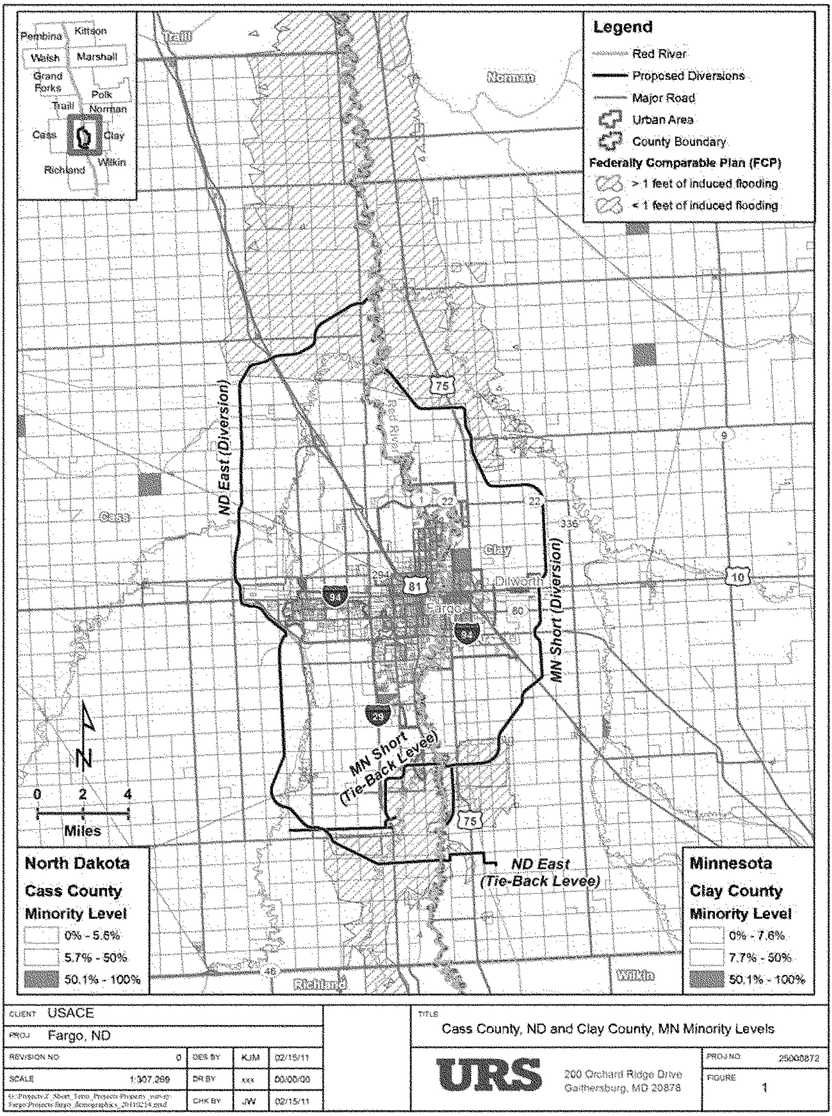


Figure 127 - Cass County, ND and Clay County, MN: Census Block Groups Showing Persons Below Poverty and Areas of Induced Flooding with the FCP– 1-percent chance event

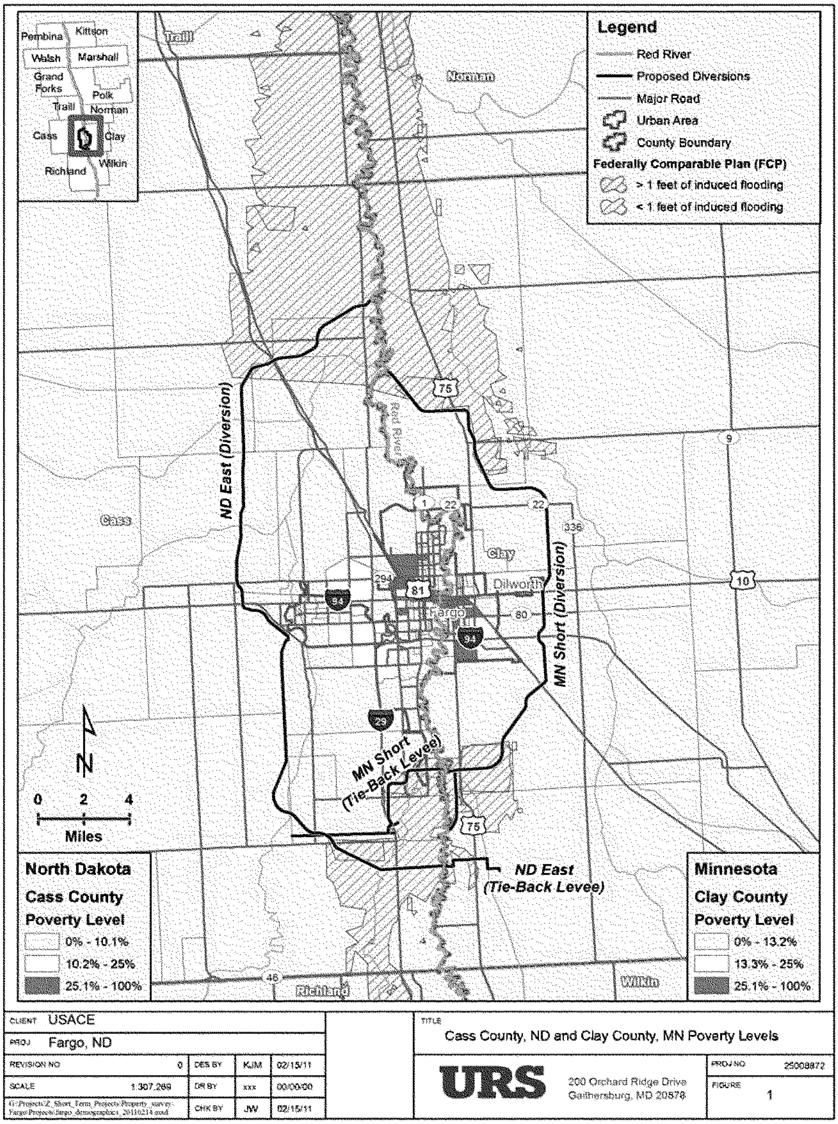


Figure 128 - Traill County, ND and Norman County, MN: Census Block Groups Showing Persons Below Poverty and Areas of Induced Flooding with the ND35K– 1-percent chance event

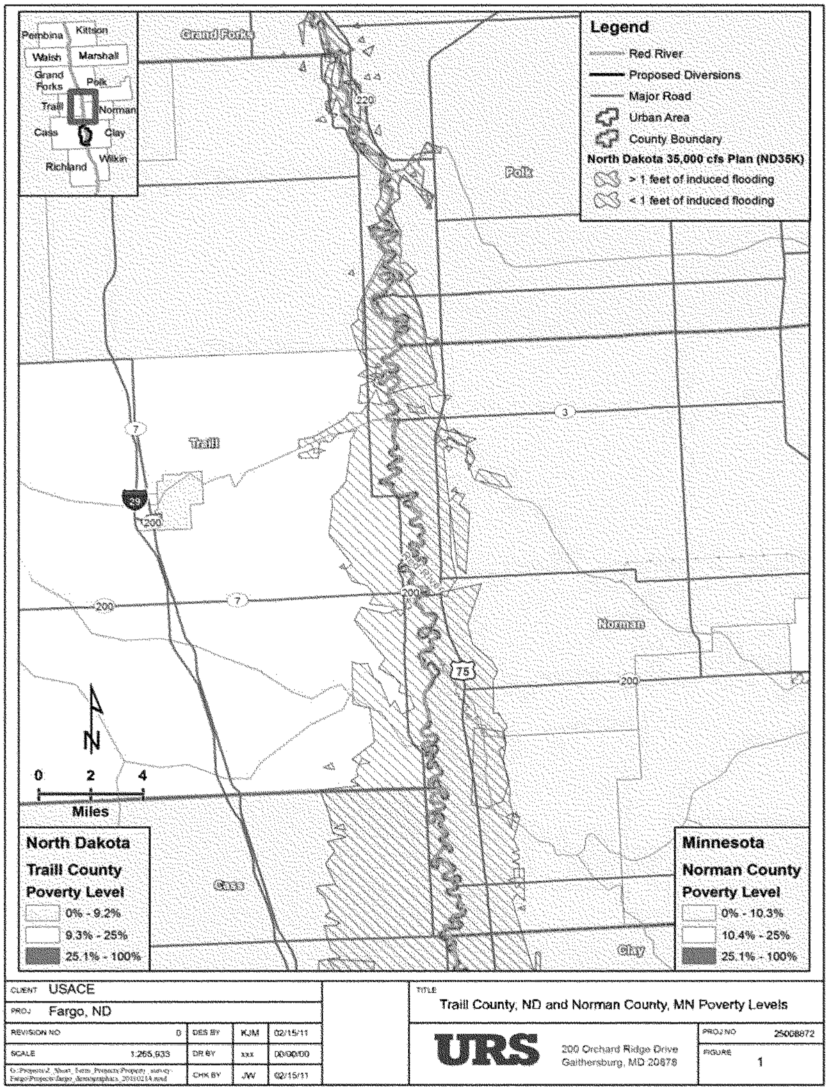


Figure 129 - Traill County, ND and Norman County, MN: Census Blocks Showing Minority Persons and Areas of Induced Flooding with the ND35K– 1-percent chance event

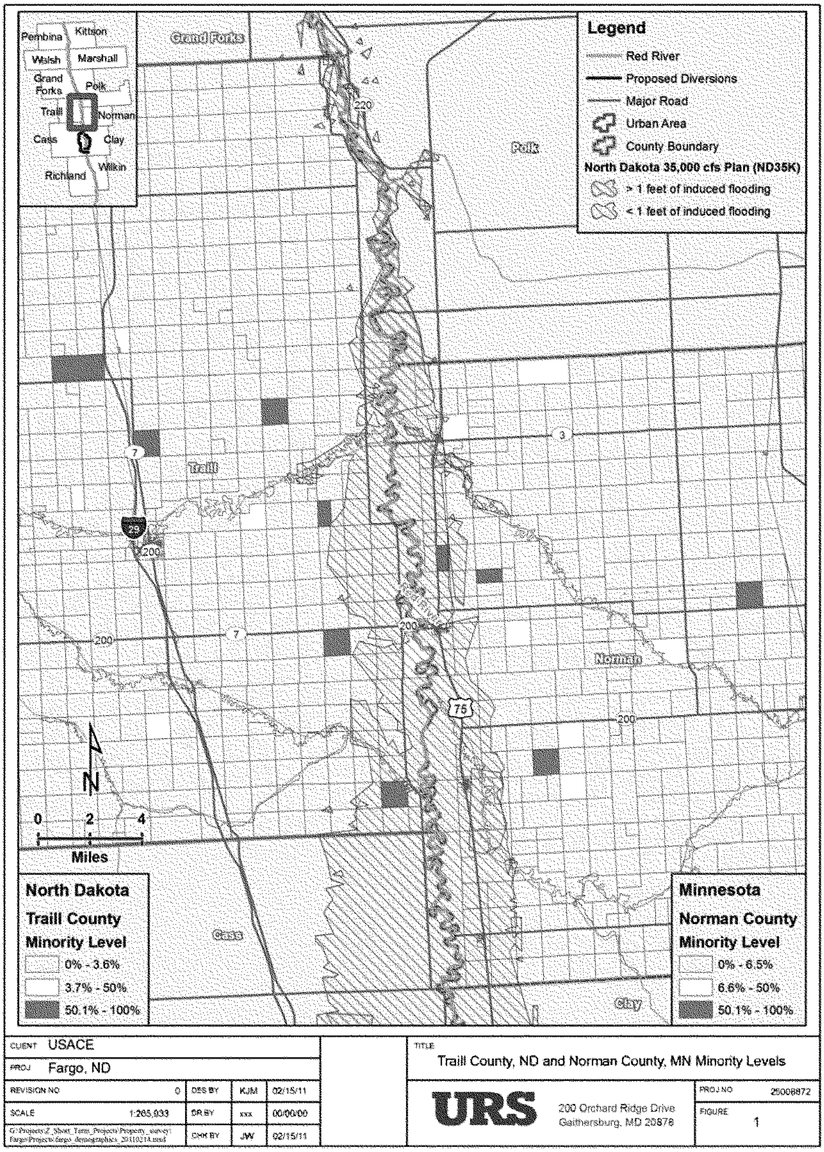


Figure 130 - Grand Forks County, ND and Polk County, MN: Census Block Groups Showing Persons Below Poverty and Areas of Induced Flooding with the ND35K– 1-percent chance event

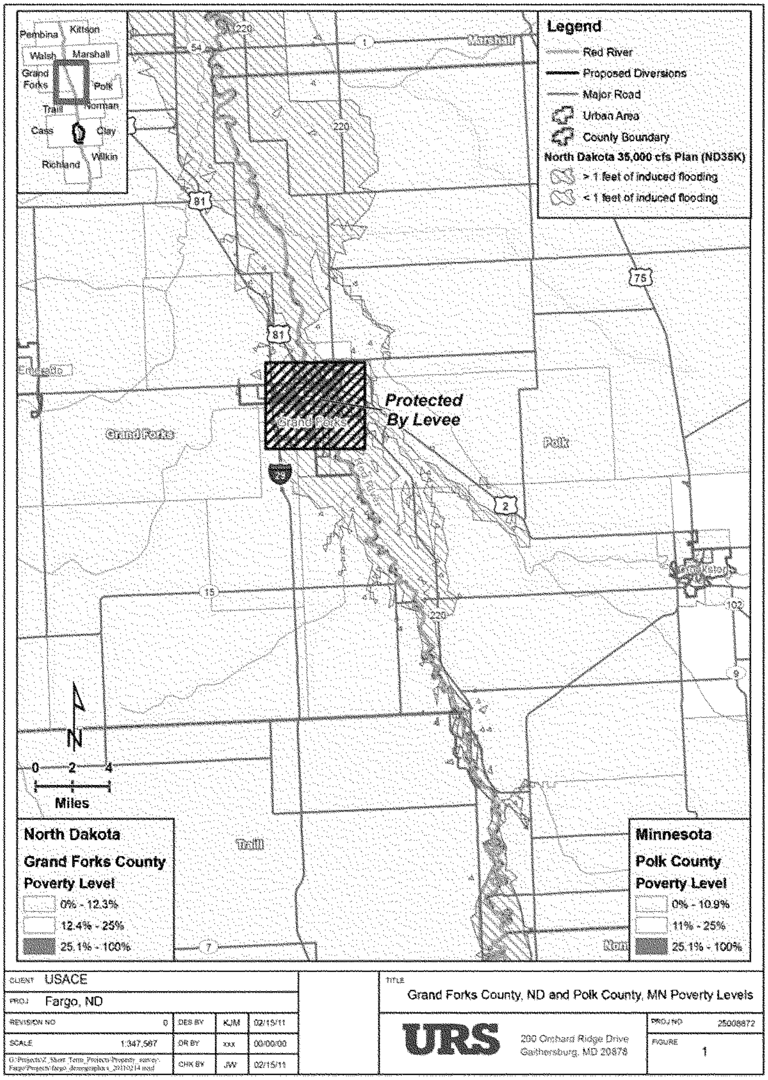


Figure 131 - Grand Forks County, ND and Polk County, MN: Census Blocks Showing Minority Persons and Areas of Induced Flooding with the ND35K– 1-percent chance event

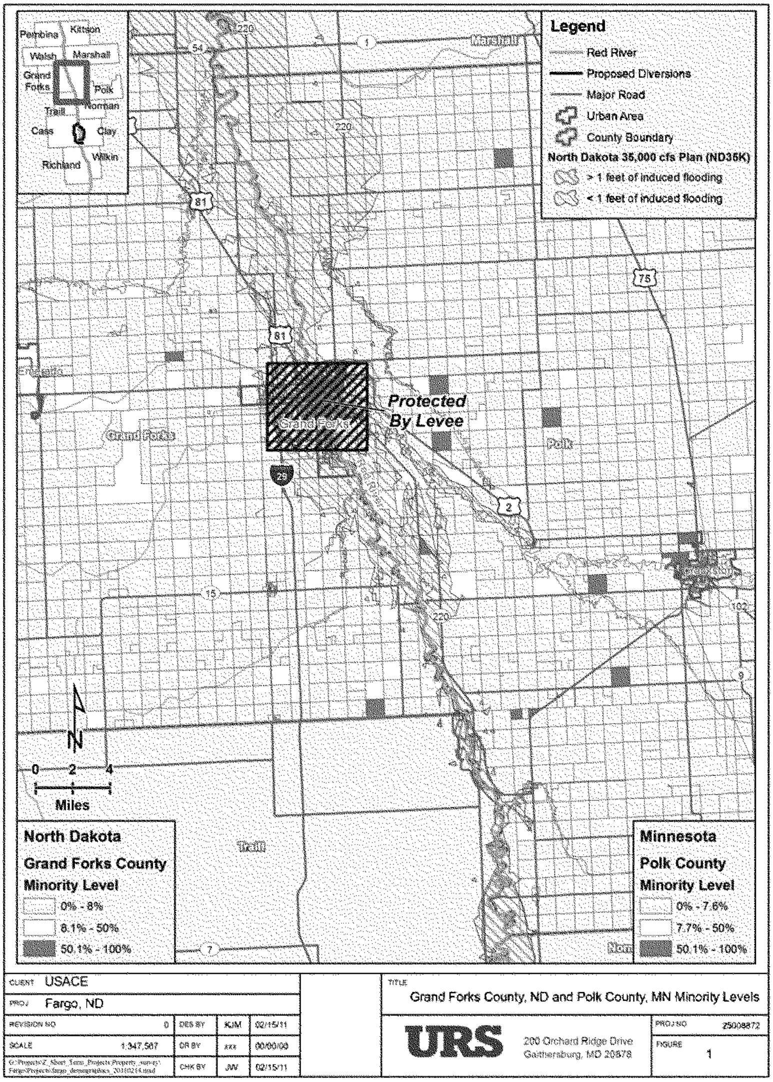


Figure 132 - Cass County, ND and Clay County, MN: Census Blocks Showing Minority Persons and Areas of Induced Flooding with the ND35K– 1-percent chance event

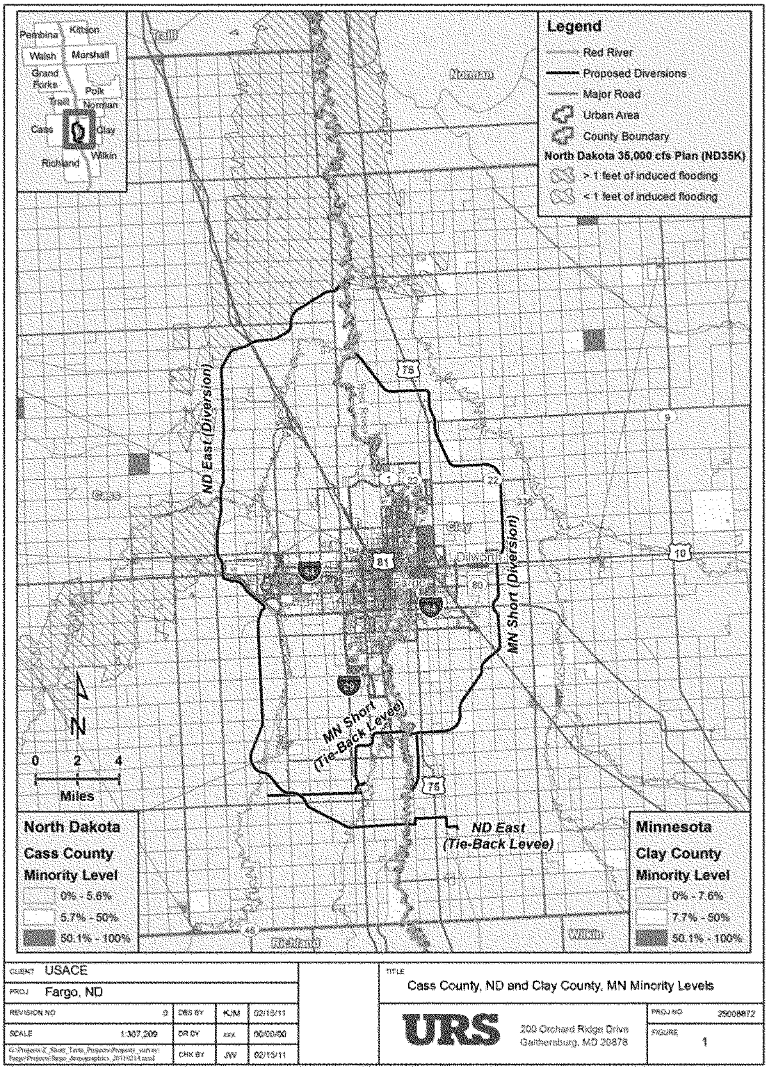


Figure 133 - Cass County, ND and Clay County, MN: Census Block Groups Showing Persons Below Poverty and Areas of Induced Flooding with the ND35K– 1-percent chance event

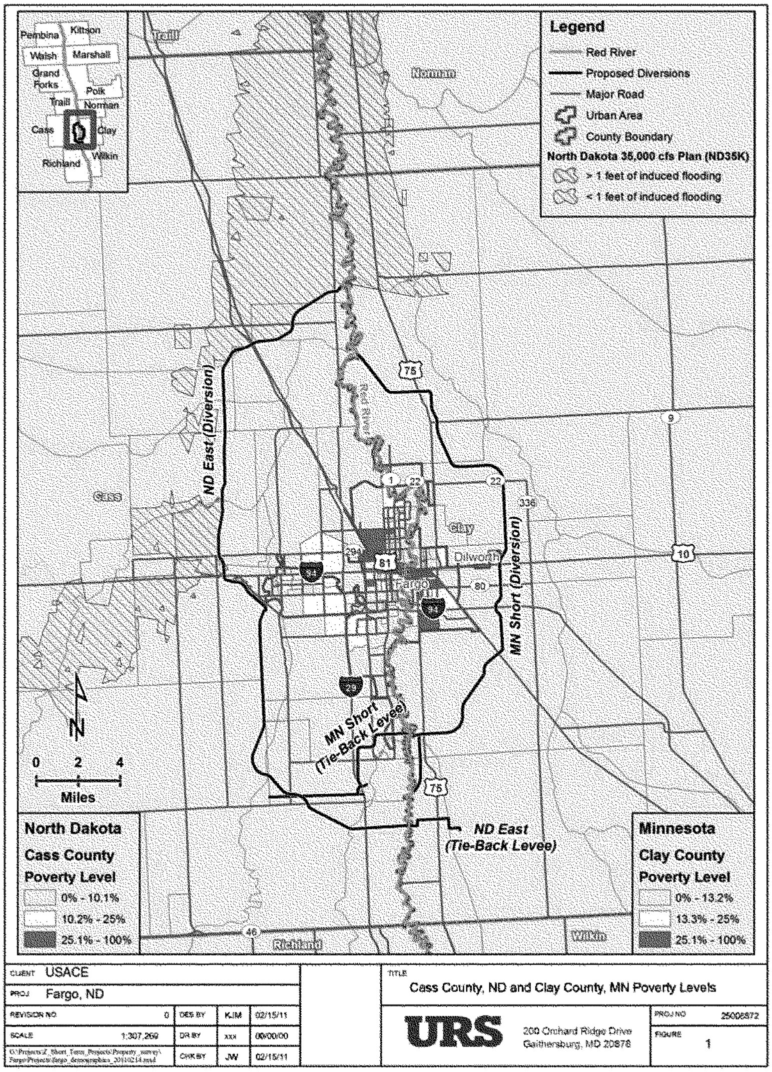


Figure 134 - Cass County, ND and Clay County, MN: Census Blocks Showing Minority Persons and Areas of Induced Flooding with the LPP – 1-percent chance event

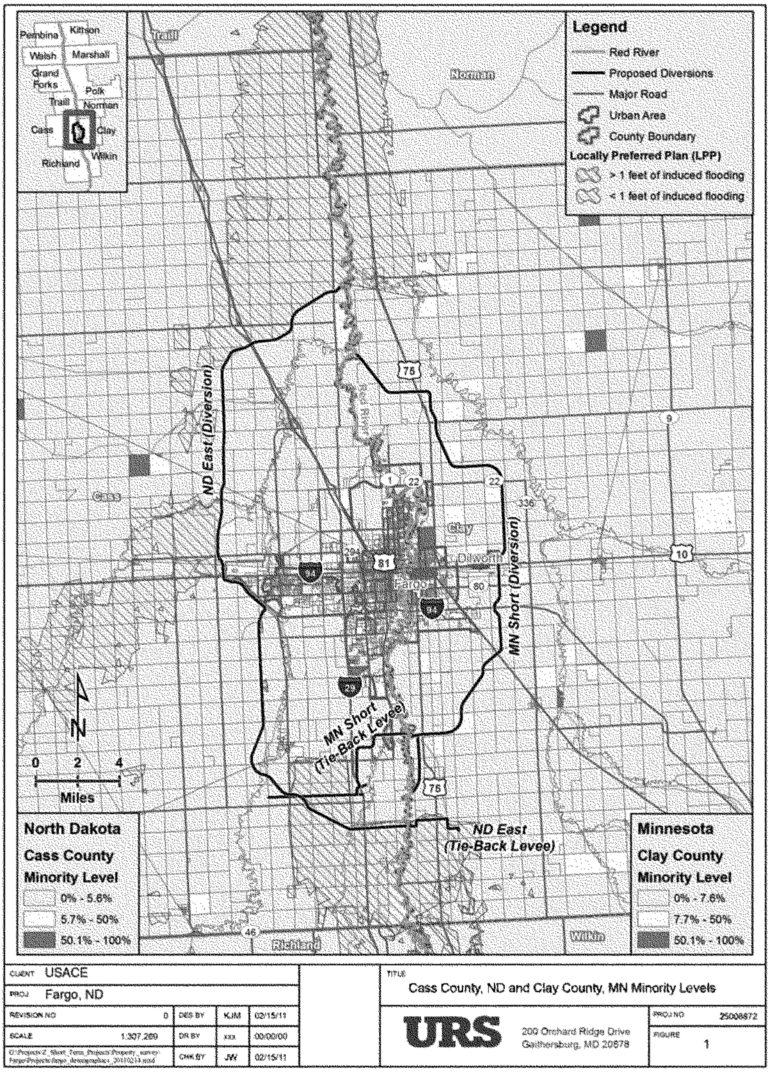


Figure 135 - Cass County, ND and Clay County, MN: Census Block Groups Showing Persons Below Poverty and Areas of Induced Flooding with the LPP – 1-percent chance event

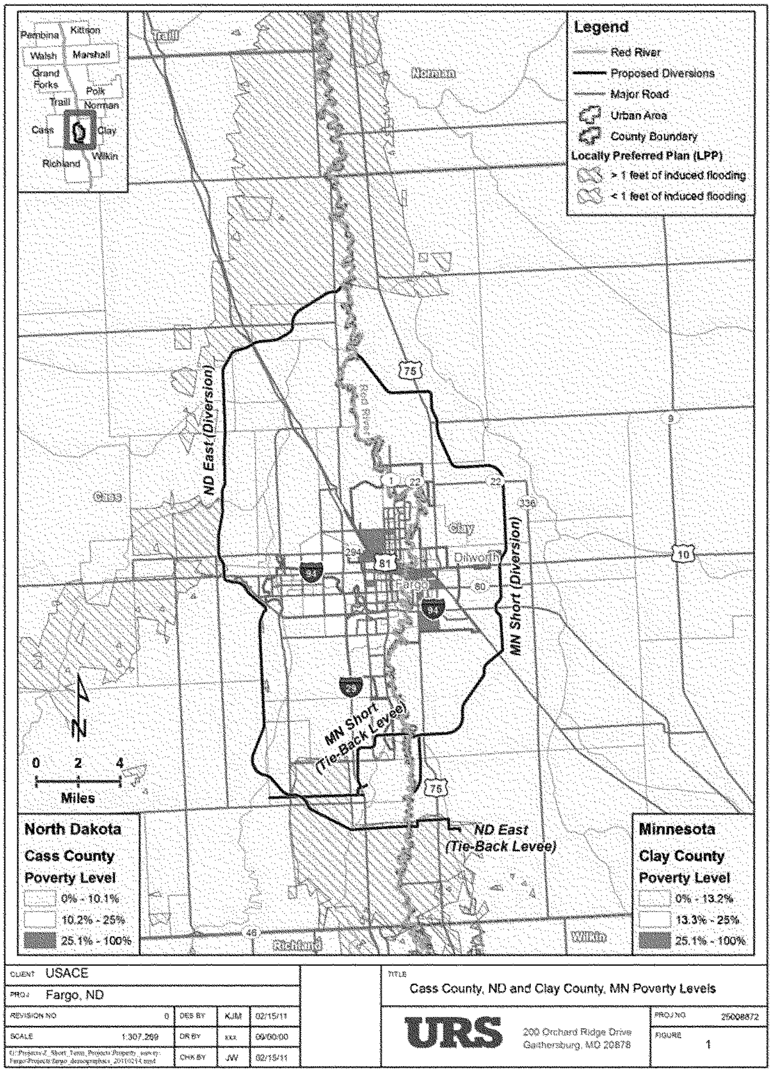


Figure 136 - Richland County, ND and Wilkin County, MN: Census Blocks Showing Minority Persons and Areas of Induced Flooding with the LPP – 1-percent chance event

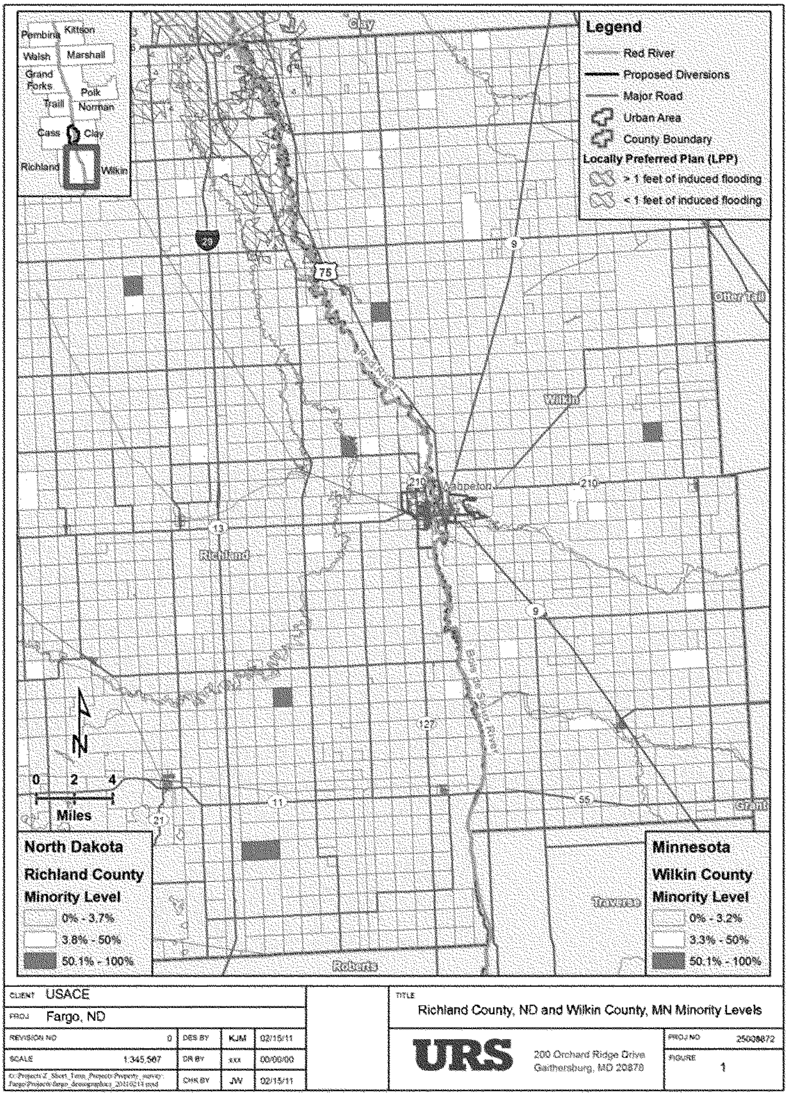
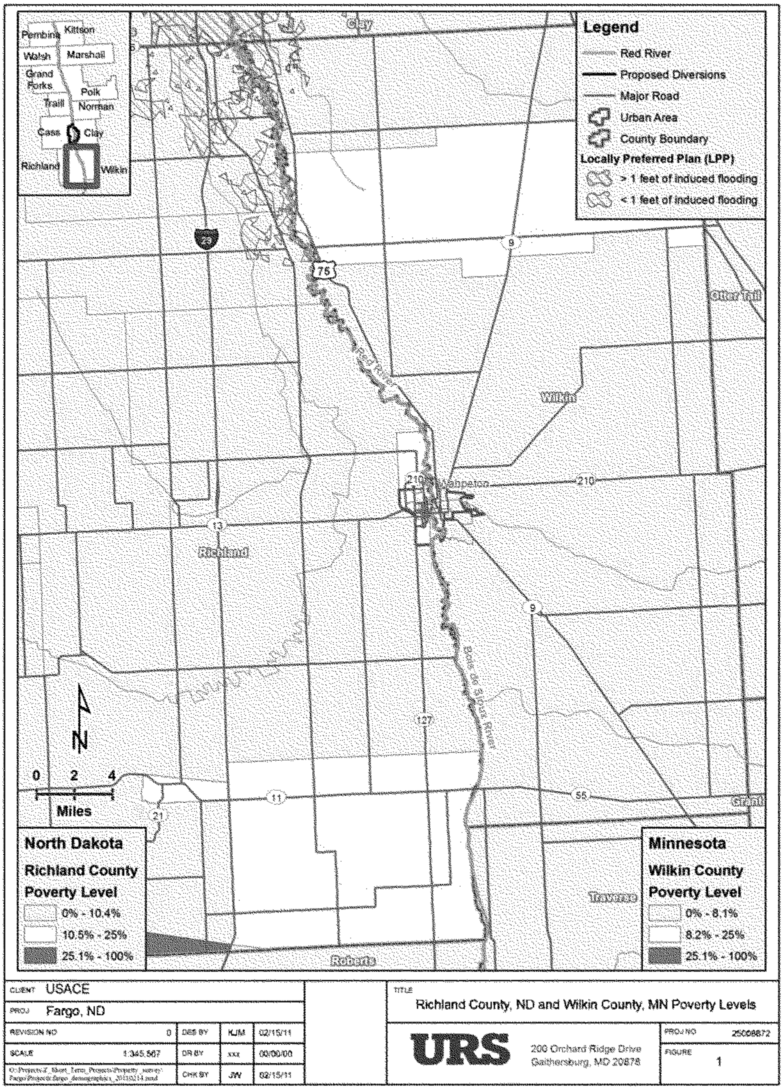


Figure 137 - Richland County, ND and Wilkin County, MN: Census Block Groups Showing Persons Below Poverty and Areas of Induced Flooding with the LPP – 1-percent chance event



5.3 CONTROVERSY

Most of the controversial aspects of the project are related to the determination of the selected plan and the location of the diversion alignments. Individual areas of controversy are discussed in various sections of the EIS and those pertaining to the socioeconomic resources are summarized here.

Some landowners near the alignments are uncomfortable with the project in their backyard, but most landowners believe that a flood risk management project is important to the area's survival. Owners of agricultural lands that are purchased for the project would be compensated at fair market value.

Landowners outside the study area are concerned about induced flooding damages to their property. All of the diversion channel alternatives have been designed to minimize increased stages in areas outside the project limits where possible. Steps will be taken to avoid, minimize, or compensate for negative impacts to these landowners. As described above, there will be some downstream and/or upstream impacts with all of the diversion channel alternatives. A preliminary takings analysis has been completed and there appear to be takings for all diversion channel alternatives.

Some concern has been expressed at public meetings that the level of protection provided by the project should be equal to that provided by the existing diversion channel in Winnipeg, Manitoba, which is a 700-year level. Other concerns regarding flood water storage have been raised by the public; this is primarily in response to the induced flooding that will occur downstream of the study area for the ND35K and FCP. There is also equal concern for the induced flooding upstream associated with the LPP.

Concerns from the city of Dilworth, Minnesota have been raised that the FCP would have serious adverse impacts to the future growth of the town. Concerns from the city of Oxbow, and other impacted cities upstream of the LPP diversion channel have been raised concerning the impacts that would be caused by the LPP, and what it will mean to their tax base, their schools, future, growth etc. Similar concerns have been raised by downstream communities in regard to the FCP and the ND35K.

Those living and working within the staging area and Storage Area would be greatly impacted by the LPP, particularly those who will need to relocate. People in those areas understandably are very against the LPP. Communities would be displaced, impacting schools, churches, and local businesses. The impacts to the lives of individuals cannot be easily conveyed, but the Corps and non-federal sponsors acknowledge that the LPP would negatively impact people in the staging area and Storage Area 1, and that there is intense opposition to the project in those areas.

The city of West Fargo and other entities have raised concern over the diversion channel alignment from Horace to West Fargo. They have requested that the alignment be moved west approximately 1.5 miles to protect infrastructure and provide additional land for their development. This is discussed further in Chapter 3 Alternatives.

5.4 CUMULATIVE EFFECTS

The Council on Environmental Quality (CEQ) regulations (40 CFR §§ 1500-1508) implementing the procedural provisions of the National Environmental Policy Act (NEPA) of 1969, as amended (42 U.S.C. § 4321 et seq.) define cumulative impact as:

> "…the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non federal) or person undertakes such other actions" (40 CFR § 1508.7).

Cumulative effects analysis recognizes that the most serious environmental impacts may result from the combination of individually minor effects of multiple actions over time, rather than the direct or indirect effects of a particular action (CEQ 1997). The challenges in assessing cumulative impacts derive in part from (1) incomplete identification of the ecological stressors or actions that alter ecological processes (2) limited data and information of suitable quality that describe the individual stressors; (3) imperfect and uncertain understanding of the potential interactions among stressors in determining cumulative ecological impacts; (4) spatial and temporal scales relevant to the overall assessment; and (5) limited understanding of the resilience of potentially affected resources to past, present, and future stress (USEPA 1997).

The CEQ has suggested frameworks for incorporating cumulative effects analyses (CEA) into the environmental impact assessment process, and steps for conducting the CEA (CEQ 1997). These frameworks are shown in Table 57 and Table 58. These frameworks indicate that the CEA should begin with the NEPA scoping process, and continue throughout the descriptions of the affected environment and the environmental effects of the action. Individual steps in conducting a CEA are also tied to these three major components of the NEPA process. Three fundamental elements typically characterize CEA (Spaling and Smit 1993 in Canter 1999): 1) a cause or source of change (perturbations); 2) the process of change as reflected via the pertinent system structure or processes; and 3) the result of the change (effect).

Table 57 – CEQ framework for conducting cumulative impact assessments.

1. Cumulative effects are caused by the aggregate of past, present, and reasonably foreseeable future actions. The effects of a proposed action on a given resource, ecosystem, and human community include the present and future effects added to the effects that have taken place in the past. Such cumulative effects must also be added to effects (past, present, and future) caused by all other actions that affect the same resource.
2. Cumulative effects are the total effect, including both direct and indirect effects, on a given resource, ecosystem, and human community of all actions taken, no matter who (Federal, non-Federal, or private) has taken the actions. Individual effects from disparate activities may add up or interact to cause additional effects not apparent when looking at the individual effects one at a time. The additional effects contributed by actions unrelated to the proposed action must be included in the analysis of cumulative effects.

3. Cumulative effects need to be analyzed in terms of the specific resource, ecosystem, and human community being affected. Environmental effects are often evaluated from the perspective of the proposed action. Analyzing cumulative effects requires focusing on the resource, ecosystem, and human community that may be affected and developing an adequate understanding of how the resources are susceptible to effects.
4. It is not practical to analyze the cumulative effects of an action on the universe; the list of environmental effects must focus on those that are truly meaningful. For cumulative effects analysis to help the decision-maker and inform interested parties, it must be limited through scoping to effects that can be evaluated meaningfully. The boundaries for evaluating cumulative effects should be expanded to the point at which the resource is no longer affected significantly or the effects are no longer of interest to affected parties.
5. Cumulative effects on a given resource, ecosystem, and human community are rarely aligned with political or administrative boundaries. Resources typically are demarcated according to agency responsibilities, county lines, grazing allotments, or other administrative boundaries. Because natural and sociocultural resources are not usually so aligned, each political entity actually manages only a piece of the affected resource or ecosystem. Cumulative effects analysis on natural systems must use natural ecological boundaries and analysis of human communities must use actual sociocultural boundaries to ensure including all effects.
6. Cumulative effects may result from the accumulation of similar effects or the synergistic interaction of different effects. Repeated actions may cause effects to build up through simple addition (more and more of the same type of effect), and the same or different actions may produce effects that interact to produce cumulative effects greater than the sum of the effects.
7. Cumulative effects may last for many years beyond the life of the action that caused the effects. Some actions cause damage lasting far longer than the life of the action itself (e.g., acid mine drainage, radioactive waste contamination, species extinctions). Cumulative effects analysis needs to apply the best science and forecasting techniques to assess potential catastrophic consequences in the future.
8. Each affected resource, ecosystem, and human community must be analyzed in terms of its capacity to accommodate additional effects, based on its own time and space parameters. Analysts tend to think in terms of how the resource, ecosystem, and human community will be modified given the action's development needs. The most effective cumulative effects analysis focuses on what is needed to ensure long-term productivity or sustainability of the resource.

[1]From: CEQ. 1997. Considering cumulative effects under the National Environmental Policy Act. Council on Environmental Quality, Executive Office of the President, Washington, D.C. 64 pages + appendices.

Table 58 – Steps in cumulative effects analysis to be addressed in each component of environmental impact assessment.

EIA Components	CEA Steps
Scoping	1. Identify the significant cumulative effects issues

	associated with the proposed action and define the assessment goals. 2. Establish the geographic scope for the analysis. 3. Establish the time frame for the analysis. 4. Identify other actions affecting the resources, ecosystems, and human communities of concern.
Describing the Affected Environment	5. Characterize the resources, ecosystems, and human communities identified in scoping in terms of their response to change and capacity to withstand stresses. 6. Characterize the stresses affecting these resources, ecosystems, and human communities and their relation to regulatory thresholds. 7. Define a baseline condition for the resources, ecosystems, and human communities.
Determining the Environmental Consequences	8. Identify the important cause-and-effect relationships between human activities and resources, ecosystems, and human communities. 9. Determine the magnitude and significance of cumulative effects. 10. Modify or add alternatives to avoid, minimize, or compensate for significant cumulative effects. 11. Monitor the cumulative effects of the selected alternative and adapt management.

[1]From: CEQ. 1997. Considering cumulative effects under the National Environmental Policy Act. Council on Environmental Quality, Executive Office of the President, Washington, D.C. 64 pages + appendices.

The geographical extent is broadly defined by the Red River of the North Drainage Basin. The pertinent time scale for assessing cumulative impacts spans approximately 160 years, and dates from 1901, the beginning of the existing discharge records for the USGS gauge at Fargo, through 2060, the end of the project planning horizon.

This section will briefly review the affected environment, which was described in detail earlier in Chapter 4, describe the stressors that have shaped and will continue to shape the natural and human environments of the Red River Basin, and then consider the cumulative effects of the impacts presented earlier in this chapter.

5.4.1 Cumulative Impacts with Diversion Channel Alternatives

The CEA will focus on the same resource categories described in Chapter 4, Affected Environment, and further evaluated for likelihood of direct and/or indirect impacts in this chapter. These include the following:

Natural Resources
Geomorphology
Air Quality
Water Quality

Water Quantity
Shallow Groundwater
Aquatic Habitat
Fish Passage
Wetlands
Upland Habitat/Riparian Habitat
Endangered Species
Prime and Unique Farmland
Climate

Cultural Resources
Cultural Resources

Socioeconomic Resources
Social Effects
Economic Issues
Environmental Justice

5.4.1.1 Geomorphology
The Red River basin has stream hydraulics that have been modified by tiling and draining activities. Many dams also have been constructed throughout the basin, including several on rivers immediately within the study area. A flood diversion project also exists within the study area for the Sheyenne River. This diversion project serves as a proxy for many potential geomorphic impacts under the diversion channel alternatives. Observations on the Sheyenne River adjacent to the diversion project suggest minimal changes to sediment transport and stream cross sections, even after the project has been in place for 20 years. This suggests fairly minimal effects to Sheyenne River geomorphology as a result of the project.

Sediment transport in the Red River and its tributaries is dominated by fine-grained sediments that easily remain suspended in the water column. All of the diversion channel alternatives could alter hydraulic conditions for the Red River. The ND35K and LPP would also affect five tributaries and Wolverton Creek. However, none of the diversion channel alternatives would substantially alter sediment transport or other key geomorphic properties. Ultimately, it is not anticipated that any of the alternatives would substantially contribute to any adverse geomorphic conditions either downstream or upstream of the study area. While channel slope could be increased for short areas adjacent to several project structures, careful project design should minimize any potential for destabilization of the stream bed or stream banks.

5.4.1.2 Air Quality
The Fargo-Moorhead area is considered a NAAQS Attainment Area for all air quality parameters (USEPA 2009). Heavy equipment would produce small amounts of hydrocarbons in exhaust emissions. The construction contractor would be required to maintain the vehicles on the sites in good working order to minimize exhaust emissions. Fugitive dust could also result from proposed construction activities so the contractor would be required to conduct dust suppression

activities. Adverse impacts to air quality resulting from the diversion channel alternatives would be minor and short term in nature regardless of the alternative that is implemented.

5.4.1.3 Water Quality
As outlined above, water quality in the Red River of the North main stem is generally impaired for much of its length in the continental U.S. Point and non-point sources of pollution result in high concentrations of several pollutants. This results in non-support of aquatic life and overall use; and partial support of swimming, agriculture, and wildlife uses. These impairments are largely due to various agricultural activities, urban runoff, septic systems, channelization, dredging, streambank modifications, dams and other stressors. Water quality within tributaries of the study area face similar water quality limitations discussed above.

The diversion channel alternatives considered here could slightly affect water quality that has already been greatly reduced. Construction of any of the alternatives could result in minor reductions in water quality, although the effects would be temporary. Potential geomorphic effects could result in slight increases in turbidity. However, the likelihood of geomorphic effects appears small, and for areas where such effects are more likely, mitigation would be applied to reduce those effects. None of the diversion channel alternatives would further contribute to other pollutants affecting water quality, such as nutrients, pH, fecal coliform or Biological Oxygen Demand. Thus, the diversion channel alternatives should not significantly contribute to further cumulative degradation of water quality in the basin.

5.4.1.4 Water Quantity
The quantity of water flowing through the Red River system has changed over time. As outlined above, review of annual peak discharge data suggests that flooding at Fargo, ND has increased over time. This includes a general increase in the frequency and magnitude of flood events. Causes of this are a likely combination of increased precipitation over time, as well as increased tiling and draining of the watershed. This has resulted in more water flowing through the system more quickly.

All of the diversion channel alternatives will change the timing and flows of water, significantly reducing the quantity of water flowing through the communities of Fargo and Moorhead. However, all diversion channel alternatives also include an increase in water quantity for areas downstream and/or upstream of Fargo-Moorhead. These impacts are outlined above, and include anticipated impacts for the 10, 2, 1 and 0.2-percent chance events. Impacts would extend approximately 220 miles downstream for the FCP and even further downstream for the ND35K, and as far as 15 miles upstream for the LPP. Ultimately, all diversion channel alternatives would result in varying improvements in the cumulative condition of water quantity and flood elevations for the Fargo-Moorhead Metropolitan area. Conversely, all alternatives will increase flood elevations and alter the timing of flooding for areas downstream and/or upstream of the Fargo-Moorhead Metropolitan Area.

5.4.1.5 Shallow Groundwater
Shallow groundwater in the study area includes the Buffalo Aquifer to the east, and the West Fargo Aquifer to the west. The Buffalo Aquifer is located five to seven miles east of Moorhead,

trending north-south. The aquifer is about 25-30 miles long, 1 to 2 miles wide and as deep as 250-feet. The top of the aquifer is at ground surface in some areas and buried in glacial lake clays in others. The West Fargo aquifer occurs around West Fargo. However, this aquifer is at least 70 feet deep.

Based on the available data, the FCP is approximately one thousand feet west of the Buffalo Aquifer, which provides a reasonable buffer between the aquifer and an excavated diversion channel. Measureable impacts to the aquifer with this separation are very unlikely. The West Fargo aquifer appears to be deep enough to avoid impacts that could occur from project structures or excavation associated with either of the North Dakota alternatives.

Additional data analyses and design refinements are recommended to verify alignment choices versus the local variations in the hydrogeology. However, none of the diversion channel alternatives should have adverse impacts to the cumulative condition of aquifers in the region.

5.4.1.6 Aquatic Habitat

Aquatic habitat includes the Red River mainstem and tributaries. This riverine habitat is occupied by many species of fish and invertebrates. This habitat also has been affected by many human influences. Activities such as stream channelization, damming and other alternations over the last 100 years have influenced hydrology, geomorphic processes and physical aquatic habitat. Additionally, alterations to the watershed, including changing to agricultural landcover, artificial drainage and tiling, have further influenced these processes. Today, habitat quality on the Red River and adjacent tributaries appears greatly reduced over that of pre-European settlement. Tributaries such as the Rush River, Lower Rush River and Wild Rice River appear greatly affected. The Sheyenne River, Maple River and Red River mainstem may be in slightly better condition, though habitat here is also degraded relative to pre-settlement conditions.

All of the diversion channel alternatives could further degrade aquatic habitat quality that has already been greatly reduced. Impacts would be greater for the LPP and ND35K, and lesser for the FCP. As outlined above, significant impacts from the project footprint for any diversion channel alternative would be mitigated through improvement of similar habitat within the basin. Geomorphic impacts generally appear small, thus the forces that form and shape river habitat would not be substantially affected. All alternatives include measures to avoid and minimize impacts. They also include mitigation to further reduce any remaining significant impacts. Ultimately, with proposed mitigation, the LPP, FCP and ND35K would not be expected to significantly contribute to further cumulative degradation to aquatic habitat in the basin.

5.4.1.7 Fish Passage and Biological Connectivity

Biological connectivity has changed greatly over time in the Red River Basin. Prior to European settlement, fish had full access to move throughout the Red River mainstem, and between its tributaries. Following settlement, many dams were constructed to facilitate water supply, floodwater storage and other goals. This included eight dams on the Red River, and hundreds of dams on tributaries throughout the basin. Dam construction began in the late 1800s, and continued through 1970.

Over approximately the last 15 to 20 years, biological connectivity has begun to improve in the basin. Fish passage projects have improved biological connectivity on five dams of the Red River Basin, with the three remaining dams currently under consideration for potential future fish passage improvements. An additional 30 projects have been implemented to improve fish movement on Red River tributaries. Although many impediments still remain, the level of biological connectivity has slowly improved in the basin.

The LPP could have a potentially significant impact to aquatic habitat connectivity on the Red and Wild Rice rivers. As such, the LPP includes several minimization and mitigation measures to reduce the level of this impact. Interrupted connectivity would be mitigated under the LPP to minimize the contribution toward this cumulative condition.

The FCP and ND35K could slightly reduce the level of biological connectivity relative to existing conditions. However, any effects would be small. The FCP and ND35K include extensive measures to minimize impacts to connectivity to levels that would be less than significant in terms of effects to long-term Red River fish populations and community trends. The FCP will have the least effect to connectivity, as impacts are limited to the Red River mainstem. The ND35K would be slightly worse as connectivity could affect the Red and Wild Rice rivers. However, under these two alternatives, significant efforts were made to minimize impacts to connectivity. Any reductions to biological connectivity would be small and not anticipated to noticeably affect fish populations or communities of the Red River or associated tributaries.

Ultimately, the LPP, FCP and ND35K could slightly reduce levels of biological connectivity to varying degrees. However, with proposed minimization and mitigation measures for each alternative, these reductions would be negated, and not significantly affect fish populations or communities, relative to existing conditions.

5.4.1.8 Wetlands

Anderson and Craig (1984, as reported in Aadland et al 2005) estimated over 95% of the wetlands in the Agassiz Lake Plain ecoregion have been drained. This number may have increased since that evaluation in 1984. Clearly, wetlands are a natural resource that has been severely impacted through human development. Due to increasing pressure to either urbanize or improve drainage on cropland, it is anticipated that wetland acreage will either remain the same or decrease within the study area in the future even without implementation of any of the diversion channel alternatives.

Wetland areas would be impacted under any of the diversion channel alternatives. These impacts are outlined above. Impacts would occur either directly through impacts from the project footprint, or indirectly through reduced hydraulic connectivity of wetlands to the river because of reduced river flood discharge. However, as outlined above, these impacts should be offset. Wetlands that will be adversely affected by the footprint of the diversion channel would be more than offset by creation of wetlands within the diversion channel bottom. Wetlands potentially impacted because of altered connectivity will be mitigated through wetland creation.

Ultimately, all the diversion channel alternatives would include appropriate measures to avoid, minimize and compensate for potential losses to wetland areas. Any of the alternatives considered here would not contribute to further cumulative degradation of wetland habitats in the basin.

5.4.1.9 Upland Habitat
European settlement resulted in the conversion of landcover type over the vast majority of the basin. Previous upland habitats have almost entirely been converted to cropland, with a mixture of hayed pasture, hobby farms and some urban development around larger cities. The remaining wooded areas, which are primarily riparian corridors, are an important wildlife and aesthetic resource.

For all the diversion channel alternatives, there would be some areas where forested habitat would be cleared. The loss of these wooded areas would be permanent but would be offset, at no less than a 1:1 ratio, by tree plantings that would be done along land that will be acquired along one of the tributaries as part of the mitigation. The other areas to be disturbed are currently farmed and have reduced natural resource value. Portions of the spoil areas adjacent to the diversion channel would be available for farming after completion. All other disturbed areas would be replanted with native species, primarily grasses that would have positive impacts on the area's overall habitat value. Overall, the construction activities would have temporary adverse impact on the terrestrial habitat but the eventual changes in vegetative cover would have long term beneficial impacts on the avian and small mammal groups which are found in areas on the periphery of residential development and agricultural plots. All diversion channel alternatives would have a small, beneficial effect to the existing condition of upland habitat.

5.4.1.10 Endangered Species
Degradation of habitat in the basin has contributed to reduced abundance and federal listing of select species. This has included the whooping crane (*Grus americanus*; endangered), the gray wolf (*Canis lupus;* endangered) the Western prairie fringed orchid (*Platanthera praeclara*; threatened), and the Dakota skipper (*Hesperia dacotae*; candidate). None of the diversion channel alternatives would contribute to cumulative impacts on these species.

5.4.1.11 Prime and Unique Farmland
Prime farmland is a valuable resource for the region. This farmland has developed through the conversion of previous natural landcovers, and through improvements such as tiling and draining. A large percentage of the study area includes prime and unique farmland.

Long-term impacts from the FCP, ND35K, or LPP would include loss of farmland and business income. The three diversion channel alternatives would result in the loss of 5,800 to 6,900 acres of prime and unique farmland (Appendix F). All of the diversion channel alternatives would contribute to the cumulative loss of this resource.

5.4.1.12 Climate
The Council on Environmental Quality (CEQ) has issued draft guidance to agencies on how to address climate change. Draft NEPA Guidance on Consideration of the Effects of Climate

Change and Greenhouse Gas Emissions, Memorandum for Heads of Federal Departments and Agencies, February 18, 2010. CEQ acknowledges that "In many cases, the GHG emissions of the proposed action may be so small as to be a negligible consideration", and set a reference point of 25,000 tons of direct CO2 or equivalent emissions annually as a useful indicator for action-specific evaluation of GHG emissions and disclosure of that analysis in their NEPA documents. Where a proposed Federal action that is analyzed in an EA or EIS would be anticipated to emit GHGs to the atmosphere in quantities that the agency finds may be meaningful, it is appropriate for the agency to quantify and disclose its estimate of the expected annual direct and indirect GHG emissions in the environmental documentation for the proposed action. In this case, the direct GHG emissions would be limited to those related to construction of the diversion channel alternatives, and would cease upon conclusion of construction. As discussed in section 5.2.1.2 Air Quality, heavy equipment would produce small amounts of hydrocarbons in exhaust emissions compared to total hydrocarbon emission in the area. The construction contractor would be required to maintain the vehicles on the sites in good working order to minimize exhaust emissions. The GHG emissions from the short-term construction of any of the diversion channel alternatives would not be meaningful.

5.4.1.13 Cultural Resources

5.4.2.13.1 Cumulative Effects on Historic Properties

For any of the diversion channel alternatives, project features (diversion channel with associated spoil piles, the associated tie-back levees, and, for the FCP, the breakout channels with associated spoil piles) may have indirect visual impacts on any National Register eligible or listed historic properties located within one-half mile of the features. Conversely, once constructed, project features would have a beneficial effect for historic properties in the cities of Fargo and Moorhead and some smaller communities in Cass and Clay counties as they would protect the historic properties from future flood related damages.

Based on cultural resources investigations along other stretches of the Red, Sheyenne, and Maple rivers, prehistoric archeological sites tend to occur on the edge of uplands overlooking the river valley and within one-quarter mile of riverbanks, with older, buried sites likely on river terraces. Any archeological sites lost as a result of project construction will be in addition to those lost to past urban and/or agricultural development in the Fargo-Moorhead portion of the Red River Basin.

5.4.1.14 Socioeconomic Resources

5.4.1.14.1 Economic Issues

With any of the diversion channel alternatives in place, development could increase at a slightly greater rate than it would without a project in place, with the added protection provided by the project features. This increase in development would also come at a cheaper cost because the requirements for developing will change because of the provided protection.

5.4.1.14.2 Recreational Opportunities
Recreational opportunities will not be adversely impacted by any of the diversion channel alternatives, but will be increased under all of them. Recreational amenities will be part of the project design and will be incorporated into whichever alternative is selected.

5.5 MITIGATION AND ADAPTIVE MANAGEMENT
This section describes the potential to avoid, minimize and compensate for adverse impacts; and provides mitigation cost estimates (in year 2011 dollar values) for implementation of any of the diversion plans considered. It also discusses the adaptive management approach to evaluating impacts over time, and assessing the effectiveness of mitigation measures. Mitigation strategies were developed for each diversion channel alternative to support the National Economic Development (NED) analysis. Mitigation strategies were not developed for the no-action alternative because this alternative would have no construction or site-specific impacts.

The Council on Environmental Quality (CEQ) has identified five components to mitigation. These include: 1) avoiding the impact altogether by not taking a certain action or parts of an action; 2) minimizing impacts by limiting the degree or magnitude of the action and its implementation; 3) rectifying the impact by repairing, rehabilitating, or restoring the affected environment; 4) reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; and 5) compensating for the impact by replacing or providing substitute resources or environment.

Measures to avoid or minimize adverse impacts were considered as part of this analysis through modification of project designs. Ideally, project designs would be tailored to avoid all impacts. However, that is not practicable. The FCP has fewer ecological impacts than the ND35K and LPP. Ecological impacts would likely be the greatest under the LPP. However, several factors are involved with selection of a preferred plan, including ecological, economic and social impacts; public input; sponsor preferences; and other related factors. In cases where significant impacts could not be avoided or minimized to levels that were less than significant, mitigation actions are proposed to compensate for the loss of habitat or ecological function.

The analysis below and in Attachment 6 provides a habitat-based assessment of impacts and mitigation measures for aquatic habitat, connectivity, floodplain forest and wetland resources. It assesses losses of habitat over time, describes various alternatives for mitigating habitat losses, and compares the costs and benefits of these alternatives to provide a basis for mitigation planning. For this analysis, benefits of mitigation measures are based on potential habitat conditions likely to result from a potential action. As required by Corps policy, a Cost Effectiveness and Incremental Cost Analysis (CE/ICA) was performed with these various alternatives to identify which provided the best option for mitigation for the given restoration action.

There are many restoration measures that could be used to compensate for unavoidable impacts of project alternatives. These mitigation measures are described briefly in this mitigation plan, with a more detailed discussion in Attachment 6. Preliminary candidate sites have been identified, and will continue to be pursued in the following months. However, specific mitigation plans, including the exact mitigation sites, have not been finalized because additional planning and evaluation are still underway. The plans through this feasibility phase provide assurance on the types of mitigation that would be implemented, that the mitigation would offset project impacts, and provide an estimate of costs required for mitigation and adaptive management actions for the study. Further refinement of the combinations, timing, and placement of mitigation actions will occur during detailed planning for individual mitigation projects. Any future mitigation planning would go through additional agency coordination, including possible future supplemental NEPA documentation, as appropriate.

This plan identifies the path for mitigating any remaining impacts, adaptively evaluating impacts in the future, and providing a cost basis to include as a part of overall project costs. The cost estimates below are estimates, and will be refined over time. The mitigation and monitoring plans will continue to be developed through 2011.

The Corps is committed to performing appropriate mitigation for lost ecosystem functions and values resulting from the project and implementing an adaptive management approach to evaluating impacts over time. As a part of an adaptive approach to mitigation, detailed pre-construction and/or post-construction surveys will be performed to better assess impacts and effectiveness of mitigation. Additional future actions could be performed, if needed, to modify, improve or optimize mitigation actions.

Coordination for this plan with the natural resource agencies is on-going, and largely began during from the fall of 2009. The Corps is committed to collaboratively working in the future with our federal and State agency partners and non-federal sponsors to implement project mitigation and adaptive management. Partners involved with planning for mitigation and adaptive management include the non-federal sponsors, U.S. Fish and Wildlife Service (USFWS), North Dakota Game and Fish Department (NDGF), North Dakota State Water Commission (NDSWC), North Dakota Department of Health, Minnesota Department of Natural Resources (MDNR), Natural Resource Conservation Service (NRCS), and Minnesota Pollution Control Agency (MPCA). Additional partners may be involved as needed.

The discussion below is broken into three sections. First, impacts requiring mitigation are expressed in terms of lost habitat quality and quantity. Second, the recommended mitigation measures are discussed for each resource category. Third, adaptive management is discussed to further evaluate potential impacts over time, and mitigation effectiveness. It also discusses possible actions that can be taken if mitigation does not prove effective, or if unforeseen impacts arise from the project. Detailed discussions on habitat quantification, mitigation alternatives analysis and selection are provided at Attachment 6.

5.5.1 Quantification of Lost Habitat

The amount of habitat lost by the diversion channel alternatives was first identified by reviewing project features and quantifying the area of aquatic habitat impacted. A quality factor was then applied for identified habitat quality. From the qualitative and quantitative determinations, the standard unit of measure, the Habitat Unit (HU), is calculated by multiplying habitat quantity by habitat quality. To identify general habitat changes over time, Habitat Units are averaged over the life of the project (50 years) to determine what is known as the Average Annual Habitat Units (AAHUs). A complete description of this analysis is provided at Attachment 6.

For the ND35K and LPP alignments, approximately 17 AAHUs of aquatic habitat could be lost through footprint impacts. For the ND35K, approximately 82 AAHUs of floodplain forest could be lost, along with 890 acres of non-forested wetland habitat. For the LPP, approximately 103 AAHUs of floodplain forest could be lost, along with approximately 990 acres of non-forested wetland habitat (Attachment 6).

For the FCP alignment, approximately 15 AAHUs of aquatic habitat could be lost through footprint impacts. Approximately 46 AAHUs of floodplain forest could be lost, and approximately 910 acres of non-forested wetland habitat could be lost (Attachment 6).

Connectivity impacts would be greatest under the LPP, with the project reducing access to over 2,000 AAHU of upstream Red River and tributary habitat. The LPP also would partially reduce access to upstream habitat on the Wild Rice River, though impacts would be less at approximately 350 AAHUs. Impacts would be less under the ND35K and FCP, with mitigation not proposed beyond the minimization measures already included in alternative plan design (e.g., fish passage channels).

5.5.2 Mitigation Measures

Several features have been included within project designs to minimize potential ecological effects. These include wider gates on the Red and Wild Rice River control structures; including two fish passage channels at each control structure; incorporating boulders or baffle blocks into the gate bay designs for the control structures; and other features. However, impacts remain to several resource categories even after these minimization techniques are included in the alternative designs.

The discussion below includes actions to further minimize and compensate for remaining significant impacts. Mitigation costs for alternatives under the two diversion alignments are provided in Table 59-Table 61. Further discussion of mitigation measures is provided at Attachment 6. It should be recognized these mitigation features could be refined should new information warrant switching mitigation measures or locations. Implementation of mitigation features may include subsequent NEPA documentation, if warranted.

Table 59 - Overview of mitigation actions for the ND35K.

Resource	Lost AAHUs	Mitigation Action	Cost
Aquatic Habitat	17	Stream Restoration and Fish Passage	$11.1M
Floodplain Forest	82	Convert floodplain agriculture land to floodplain forest	$1.59 M

Wetland	890 acres	Wetland creation in the bottom of diversion channel and other wetland mitigation	$17.9 M
Total:			$30,590,000

Table 60 - Overview of mitigation actions for the LPP.

Resource	Lost AAHUs	Mitigation Action	Cost
Biotic Connectivity	Partially reduced access to over 2,000 AAHUs (Red River)	Construct six additional fish passage channels; Construct Drayton fish passage	$16.5M
Biotic Connectivity	Partially reduced access to approximately 350 AAHUs (Wild Rice)	Construct fish passage at Wild Rice and Hanson Dams	$8.8M
Aquatic Habitat	17	Stream Restoration and Fish Passage	$11.1M
Floodplain Forest	103	Convert floodplain agriculture land to floodplain forest	1.99 M
Wetland	990 acres	Wetland creation in the bottom of diversion channel and other wetland mitigation	$19.96 M
Total:			$58,350,000

Table 61 - Overview of mitigation actions for the FCP.

Resource	Lost AAHUs	Mitigation Action	Cost
Aquatic Habitat	15	Stream Restoration and Fish Passage	$9.7M
Floodplain Forest	46	Convert floodplain agriculture land to	$890,000

		forest	
Wetland	910 acres	Wetland creation in the bottom of diversion channel and other wetland mitigation	18.1M
Total:			$28,690,000

5.5.2.1 Fish passage mitigation for LPP.
For the LPP, six additional fish passage channels would be added to the design to accommodate fish passage across most flow conditions at the Red River control structure. This will help to further minimize impacts to connectivity.

Drayton Dam fish passage would be constructed to further offset any impacts to Red River connectivity due to the protracted operation period of the control structure. The selection of Drayton Dam is further discussed in Attachment 6. As additional information is gathered during the design and implementation phase, the mitigation may be optimized with a combination of equally effective measures to reduce this impact to levels that are less than significant.

To address remaining impacts to connectivity on the Wild Rice River, fish passage will be constructed at the Wild Rice Dam and the Hanson Dam; both are on the Wild Rice River. Reduced connectivity at the Wild Rice River control structure will be mitigated by improving connectivity at these two dams which are located above and below the proposed features under the LPP. The selection of these two dams is further discussed in Attachment 6.

5.5.2.2 Aquatic Habitat Footprint Impacts
To offset footprints impacts outlined above, the Corps proposes full stream restoration as the preferred mitigation technique. However, if adequate mitigation areas cannot be developed, the Corps also will consider stream restoration via riparian buffers, as well as fish passage, to mitigate for remaining impacts. Any of these three mitigation alternatives could provide valuable habitat benefits and offset adverse effects to lost habitat. Attachment 6 provides a detailed discussion of the mitigation analysis, including consideration of specific alternatives, costs, and CE/ICA analyses to compare various restoration alternatives. It also discusses coordination with the natural resource agencies, and their preference for mitigation methods.

The specific areas for stream restoration have not been finalized, but would be in the Red River basin, preferably near the study area. There are multiple other efforts that are considering stream meandering as a possible project. These include projects on the Mustinka, Buffalo and Wild Rice rivers, all in Minnesota. Coordination with the NRCS suggests that additional sites may be available on the Maple, Sheyenne and Wild Rice rivers in North Dakota. Preference would be given to sites first on the Red River, then on nearby tributaries (e.g., Sheyenne, Maple or Wild Rice rivers), and as a last resort, other tributaries elsewhere in the watershed. While there appears to be many opportunities for stream restoration, the willingness of landowner participation appears to be a significant obstacle to overcome with this restoration technique.

If mitigation cannot be achieved through stream restoration, then fish passage will be pursued to offset remaining impacts. This technique is different in that it provides more systemic benefits, rather than improvements at a specific site. Stream restoration is easier to assess in terms of its effectiveness in offsetting impacts. Assessment of mitigation effectiveness is more challenging with implementing fish passage. However, the benefits also could be more substantial, and benefit a broader group of organisms.

Fish passage could be constructed at one or more dams in the Red River basins. Potential sites for fish passage, include the costs and benefits of implementation, are discussed in Attachment 6 for several dams in the Red River basin. It is estimated that $11.1M would be needed to provide mitigation entirely through stream restoration for the LPP and ND35K; and $9.7M for the FCP. After site-specific habitat restoration is accounted for, remaining funds and mitigation needs will be directed towards one or more fish passage projects. Given the high value that fish passage appears to have, implementation of fish passage should provide as many overall benefits, and be as effective, as site-specific restoration.

5.5.2.3 Wetland Mitigation

For all of the diversion channel alternatives, wetland acres that will be adversely affected by diversion channel construction will be offset by the creation of wetlands within the diversion channel bottom. Features that will be used to facilitate the creation of wetlands will include meandering the low flow channel; constructing rock riffles in locations to create ponding; and other features developed during the design of the project. Vegetative species would be planted that are appropriate to temporarily flooded wetlands. A low flow channel is a channel that is typically in the center of a larger channel which is sized to handle small flows from drains, ditches or groundwater. The low flow channel would be approximately a 10 foot wide; 3 foot deep channel located in the middle of the larger diversion channel, and could meander back and forth within the 250 - 400 foot wide diversion channel bottom. The opportunity for inter-agency partnerships to develop areas for improved habitat would be explored with the non-federal sponsors, interested federal, state and local agencies and interest groups during preparation of plans and specifications. The area available on the bottom of the diversion channel for all alternatives far exceeds the amount of wetland acres that would be impacted. This large corridor of wetland habitat will be a continuous habitat corridor that rarely exists in this region, which will make it very desirable to a wide array of existing wildlife species. In accordance with Corps policy, the Corps also considered the use of mitigation banks to mitigate for wetland impacts, but the number of available credits in the watershed does not come close to the mitigation credits needed. A review of the Upper Red River of the North Wetland Bank Service Area (region 4) indicates that there are only 26 useable wetland credits available for offsetting wetland impacts. Banks are located in five Minnesota counties within this service area and available credits range from .02 in Clay County (where project is located) to 16 credits in Otter Tail County. There are no commercial wetland banks in the state of North Dakota.

Wetland areas to be created within the proposed diversion channel were analyzed using the Minnesota Routine Assessment Methodology for Evaluating Wetland Functions (MnRAM), Version 3.3. Based on the design of the diversion channel, a base flow is assumed within the channel bottom in most years, resulting in flow-through/riverine shallow marsh wetlands within the lowest portions and behind the periodic grade controls, and fresh wet meadow wetlands dominating the remaining area below the upland slope. Wetland areas will be planted with native seed mixes appropriate for the intended plant communities and managed for invasive species such as reed canarygrass (*Phalaris arundinaceae*) and purple loosestrife (*Lythrum salicaria*).

When overall wetland functions are considered the wetland development associated with the LPP is expected to fully offset any losses associated with project construction. Wetlands within the proposed diversion corridor will not be subject to the regular disking/plowing for agricultural production to which the majority of the existing wetland resources are subject. The replacement of wetland functions lost will be done within the same watershed as the impacts, adequately addressing some of the needs of the watershed.

The wetlands within the diversion corridor are expected to provide at least a "Moderate" level of functionality for *Maintenance of Hydrologic Regime, Flood/Stormwater/Attenuation, Downstream Water Quality, Maintenance of Wetland Water Quality* and *Aesthetics/Recreation/Education/Cultural* functions and values. Of course, the intent of the project itself is for flood damage attenuation, and the standing vegetation will provide for uptake of nutrients as well as longer retention of floodwaters than unvegetated conditions. The base flow in the channel will provide for sustained maintenance of hydrology within the corridor as well as to downstream resources, except in periods of extreme drought. The corridor will be visible from many public vantage points, providing an aesthetic improvement with the native vegetation and a naturalized meandering stream channel.

The wetlands will likely provide a "High" level of function for *Shoreline Protection*, situated as they are along the base flow channel. The naturalized vegetation, left untouched except for management of invasive and woody species, will maintain the streambanks by preventing erosion during the periods of high flow expected within the diversion corridor. Other "High" levels of function provided by the diversion corridor wetlands include *Maintenance of Characteristic Wildlife Habitat Structure* and *Maintenance of Characteristic Fish Habitat*. Each of these functions would be enhanced by the standing vegetation and the uninterrupted wildlife corridor provided within the diversion corridor. Only the function of *Maintenance of Characteristic Amphibian Habitat* would be provided at a "Low" level, due to the direct connection to fish habitat from area rivers.

5.5.2.4 Riparian Forest Mitigation

There would be unavoidable impacts to riparian forest habitat for all diversion alternatives. Impacts for the FCP include approximately 42 acres for the Red River control structure and outlet structure and approximately 47 acres for the diversion channel, for a total of 89 acres. Impacts for the ND35K include approximately 29 acres for the Red River control structure and outlet structure, 96 acres for the diversion channel, 20 acres for the Wild Rice River control structure, 10 acres for the Sheyenne River aquaduct and 3 acres for the Maple River aquaduct, for a total of approximately 157 acres.

Impacts for the LPP include approximately 29 acres for the Red River control structure and outlet structure, 96 acres for the diversion channel, 20 acres for the Wild Rice River control structure, 10 acres for the Sheyenne River aquaduct, 3 acres for the Maple River aquaduct and 40 acres for the storage area, for a total of approximately 199 acres.

The compensatory mitigation for these impacts would involve the restoration of existing floodplain agricultural land to floodplain forest. This land would be floodplain agricultural land that has been cleared of trees and is adjacent to and hydraulically connected by seasonal surface flow to a river within or near the study area, with a target hydrologic regime for a flood recurrence interval from 2-5 years.

The objective would be to restore riparian forest vegetation on the mitigation land similar to the vegetation types that have been lost. Targets would be to mitigate at a 2:1 ratio and to restore stand density with an average of 300 trees per acres over 80 percent of the mitigation site(s) with diameter at breast height (DBH) of 2 inches within 10 years.

5.5.2.5 Additional Mitigation Measures for Consideration

In addition to those techniques outlined above, the non-federal sponsors and the Corps will look at other measures to avoid, minimize and mitigate project impacts. This could include similar project at different locations, entirely different measures, or so combination therein. For example, one option that will be evaluated is the concept of passing more water through the protected area (e.g., discharge above 9,600 cfs at Fargo). This could require additional project features within Fargo, such as levees, but may reduce the frequency that the project needs to be put into operation.. The costs for this action and the benefits provided will be compared to other mitigation features to identify if this action warrants implementation as mitigation. In-town levees and other actions will be considered during the design phase and coordinated with the non–federal sponsors and agency partners. Additional NEPA documentation will be completed should it be required.

5.5.3 Adaptive Management

The discussion below provides a brief summary of adaptive management and project monitoring for all of the diversion channel alternatives, including an overview of activities to be done both prior to and following construction. An overview of costs associated with monitoring and adaptive management are summarized in Table 62 and Table 63. A complete discussion of monitoring and adaptive management measures, including methodology and locations, is provided at Attachment 6.

5.5.3.1 Red River:

As discussed above, footprint impacts were identified that would result in direct loss of aquatic habitat. Beyond that, it is believed that the potential for any future impacts to geomorphology, physical habitat, biotic use or biotic connectivity is low for all of the diversion channel alternatives. However, these conditions would be further verified before and after construction to ensure that these impacts have been adequately addressed.

For the Red River, the following survey assessments would be performed both pre- and post-construction:

- Geomorphic Assessment, including description of physical habitat
- Biotic Assessment to include fish and macroinvertebrate surveys
- Freshwater mussel surveys

The area assessed would generally be identified as the Red River between the upstream and downstream junctions of the diversion channel. Additional areas above and below the diversion confluences could be assessed primarily for potential geomorphic effects. . The protocols for these assessments, including methodology and survey sites, are included in Attachment 6. The biotic assessments will follow protocols used by the North Dakota Department of Health and Minnesota Pollution Control Agency (MPCA) for fish and invertebrate surveys. Mussel surveys will require their own specific protocol.

Geomorphic surveys would be performed once prior to construction, and at least once following construction. The timing of post-construction monitoring is still being considered, but would potentially be five to ten years following project completion. Additional geomorphic surveys could be warranted further into the future, the need for which would be decided by the non-federal sponsors and agency partners.

Biotic surveys would be performed at least twice prior to construction, with additional surveys under consideration. Given the variability in species distribution and abundance, and with sampling effectiveness, multiple biotic surveys events and sites will be used. The timing of post-construction monitoring also would include at least two survey events, and possibly more, performed over the first 20 years following project completion.

Monitoring also would be performed post-construction to assess fish migration through the Red River control structure, and associated fish passage channel. The exact methodology for assessing this issue is under discussion, but could include activities such as netting and/or radio telemetry. Netting could be done immediately above the control structure or fish passage channel, and would provide insight into which species are able to migrate through these features. Netting is a fairly easy and inexpensive method to use to evaluate whether fish are able to pass through project structures. However, it is not as complete as radio telemetry work. Conversely, radio telemetry could be used to assess how many fish approach the identified structures, and what portions of those fish are able to migrate through these features. This information would be extremely beneficial for not only assessing fish movement through project structures, but could provide general knowledge on effectiveness of features like fish passage channels and nature-like fishways that have not been evaluated in great detail. The drawback is that radio telemetry studies can be considerably more expensive, particularly for the equipment that is involved. It also requires the collection of fish and attachment or surgical implantation, which is labor intensive. It is biased toward larger bodied fish that can better handle the radio transmitter. There are also limitations in how long radio transmitters may last, which is problematic given the unknown of which years would have flooding events significant enough to operate the flood risk management project.

For cost estimation purposes, it was assumed the Red River would have a geomorphic assessment, three fish and macroinvertebrate surveys, and one mussel survey. These actions would be done prior to construction to characterize existing conditions. Similar monitoring would be completed post construction. For cost estimation purposes, it was assumed this would include at least two geomorphic surveys and three surveys for fish and macroinvertebrates. The non-federal sponsors and agency team would determine how long after construction the surveys would be performed. A study of post-project connectivity impacts also would be performed. A preliminary cost estimate for all surveys is provided for the diversion channel alternatives in Table 62 and Table 63.

5.5.3.2 Rush and Lower Rush Rivers:
For the ND35K and LPP, the Rush River and Lower Rush River would be redirected to flow into the diversion channel, abandoning almost six miles of tributary habitat. Given their channelized nature, habitat value may be limited. The Lower Rush habitat may be especially limited given it is intermittent. It is believed that impacts from this action would be offset because both tributaries would flow through a new meandering channel at the bottom of the diversion channel. The habitat value and biotic use, following construction, would need to be further verified to assure that these impacts have been adequately offset.

Monitoring for biotic use would be performed prior to construction within sections of the Rush and Lower Rush rivers proposed for abandonment. This includes sampling for fish and macroinvertebrates following the protocol in Attachment 6. For these two tributaries, pre-project sampling is currently proposed for a single event. Additional discussion may be warranted for pre-project surveys of the Lower Rush. If this tributary is in fact intermittent, surveys following the outlined protocol, which includes sampling during summer and late summer, may not be appropriate. The type of surveys, or the need to do fish or macroinvertebrate surveys, may need to be reevaluated. This decision would be coordinated with the agency partners.

Following construction of the project, additional surveys for biotic use would be performed within the new channel at the base of the diversion channel. Costs for pre- and post-construction surveys on the Rush and Lower Rush rivers are included in Tables 21 and 22.

5.5.3.3 Maple River, Sheyenne River, Wild Rice River and Wolverton Creek:
For the ND35K and LPP, the Maple, Sheyenne, and Wild Rice rivers, and Wolverton Creek, would include various hydraulic structures that modify tributary flood discharges between the diversion channel and the Red River. The level of hydraulic change is discussed in the aquatic habitat section above in Section 5.2.1.7, including the potential for adverse effects. However, the geomorphic condition and biotic use would need to be further verified before and after construction to ensure that these impacts have been adequately offset.

For these tributary rivers, the following survey assessment would be performed both pre- and post-construction:

- Geomorphic Assessment, including description of physical habitat
- Biotic Assessment to include fish and macroinvertebrate surveys
- Freshwater mussel surveys

Wolverton Creek will include additional survey work to evaluate potential impacts of reduced connectivity on fish community composition.

Locations and methodology for tributary surveys are included at Attachment 6. This would typically include one site within the potential footprint area, and one or more downstream reaches. It is also possible that upstream sites for biotic surveys could be used to assess whether the project has influenced biotic connectivity and upstream diversity. The protocols for these assessments also are still under development.

Geomorphic surveys would be performed in all three tributaries once prior to construction, and at least once following construction. The timing of post-construction monitoring is still being considered, but would potentially be five to ten years following project completion. Additional geomorphic surveys could be warranted further in the future, the need for which would be decided by the non-federal sponsors and agency partners.

Biotic surveys would be performed at least twice prior to construction, with additional surveys under consideration. Given the variability in species distribution and abundance, and with sampling effectiveness, multiple biotic surveys are desirable. The timing of post-construction monitoring also is under discussion, but could include multiple surveys performed over the first 20 years following project completion.

For cost estimation purposes, it was assumed pre-construction monitoring would include one geomorphic assessment, and three biotic surveys. These actions would be done in all tributaries to characterize conditions pre- and post-project. For post construction, it was assumed that monitoring would include two geomorphic assessments, and three biotic surveys. A study of post-project connectivity impacts also would be performed. Costs for pre- and post-construction surveys on the Maple, Sheyenne and Wild Rice rivers, and Wolverton Creek, are included in Tables 21 and 22. Assessment of potential impacts of reduced connectivity on Wolverton Creek are included under costs for connectivity assessments.

5.5.3.4 Monitoring at Mitigation Sites:
Implementation of any diversion channel alternative would require implementation of mitigation. As outlined above, the type and location of mitigation is still being determined. Stream restoration will be the primary mitigation method, with fish passage also providing additional mitigation for site-specific impacts. It is recognized that whatever type of mitigation is selected, monitoring will be needed to verify effectiveness.

The type of monitoring would likely be along the lines of what has been discussed here. For stream restoration efforts, monitoring would likely include pre-project assessment for geomorphic and biotic conditions similar to what has been proposed for the Red River and North

Dakota tributaries. Conversely, if fish passage is implemented, a monitoring approach similar to that outlined above for the Red River control structure could be implemented. To the extent possible, monitoring for stream restoration would be performed both pre-construction and post-construction.

The cost for pre- and post-project monitoring of mitigation sites is also included in Table 62 and Table 63 for the diversion channel alternatives. Given that specific mitigation sites are still being planned, the monitoring costs for mitigation (and thus the totals in Table 62 and Table 63) will continue to be refined, and could increase or decrease depending on the number and location of mitigation sites ultimately implemented.

Table 62 - Overview of studies for adaptive management, including post-construction evaluation of impacts and mitigation effectiveness for the FCP.

Studies	Cost
Study Area Geomorphic Assessment: Pre-construction (1 event)*	$1,000,000
Study Area Geomorphic Assessment: Post-construction (2 events)	$1,000,000
Connectivity/Fish Passage Assessment: Post Construction	$5,000,000
Biotic Use: Pre-construction (3 events)	$2,250,000
Biotic Use: Post-construction (3 events)	$2,250,000
Diversion Channel Wetlands Monitoring Post Construction	$100,000
Total Pre-Project Monitoring	$3,250,000
Total Post-Project Monitoring	$8,350,000

*Costs for pre-project geomorphic surveys are based on work already underway. Pre-project surveys will be more extensive than needed for the FCP as survey work is being completed to cover all three diversion channel alternatives.

Table 63 - Overview of studies for adaptive management, including post-construction evaluation of impacts and mitigation effectiveness for the ND35K and LPP.

Studies	Cost
Study Area Geomorphic Assessment: Pre-construction (1 event)	$1,000,000
Study Area Geomorphic Assessment: Post-construction (2 events)	$2,000,000
Connectivity/Fish Passage Assessment: Post Construction	$7,500,000
Biotic Use: Pre-construction (3 events)	$3,500,000
Biotic Use: Post-construction (3 events)	$3,500,000
Diversion Channel Wetlands Monitoring Post Construction	$100,000

Total Pre-Project Monitoring	$4,500,000
Total Post-Project Monitoring	$13,100,000

5.5.3.5 Wetlands
For the Draft EIS/Feasibility Study, wetland areas were identified using only the National Wetlands Inventory (NWI) mapping for the region. While the NWI is an excellent tool that is used on a regular basis for initial identification of potential wetland areas, there are limitations with this mapping in agricultural regions. As noted in an interagency agreement developed in the 1970s between the U.S. Fish and Wildlife Service and the USDA Natural Resources Conservation Service, "NWI maps, by design, do not show many farmed wetlands in most of the country [leading] to a significant underestimate of the amount of wetland in agricultural regions" (National Wetlands Newsletter, Vol. 19, No. 2, 1997). Therefore, the Draft EIS/Feasibility Study identified a significantly lower estimate of wetlands than was found by the field investigation for the Supplemental Draft EIS and Final EIS.

The design of the diversion channel, to include a sinuous low-flow channel, provides a number of self-mitigating factors to offset the proposed loss of wetlands on the landscape due to the project itself. The diversion channel alternatives have the opportunity to return many of these functions back to the landscape in the area. Creating and restoring wetlands within the diversion footprint will increase the retention and treatment of flood/stormwater on the landscape, rather than moving it off the landscape as quickly as possible. Wetlands within the diversion channel, no longer subject to regular farming, will reestablish natural vegetation that will treat the water quality within the wetland, resulting in improved downstream water quality. This natural vegetation will also improve wildlife habitat in the area, providing refuge for wildlife and increasing diversity of species seen in the area.

For the FCP, ND35K, and the LPP the diversion channel itself is expected to provide a functional offset for the proposed impacts; a minimum of 1,515 acres (FCP), 1,527 acres (ND35K) and 1,450 acres (LPP) of wetlands, are expected to establish within the diversion channel, including areas of seasonally flooded basin, wet meadow and shallow marsh. A more detailed discussion of the functionality of the established wetlands is in Attachment 6. This return of functionality to the landscape within the diversion channel serves as self-mitigation to compensate for the impacts to wetland resources due to the project. Floodplain forest wetlands were assessed under a separate portion of this document, where mitigation for all forested resources will be provided at a ratio of 2:1. Forested communities take longer to become established than non-forested communities, resulting in a period of time between the loss of the existing forested resource and the return of a forested community. This is referred to as temporal loss of function from the forested resource. The mitigation ratio for forested communities partly accounts for this temporal loss.

5.5.4 Future Project Modification
Future monitoring will verify the impact conclusions reached during this feasibility study, and evaluate the effectiveness of mitigation. Monitoring activities, including review of results, will be performed collaboratively between the non-federal sponsors and the agency partners. If future impacts are identified that were not mitigated for, or if mitigation has proven ineffective,

then the non-federal sponsors will work with the Corps and the partner agencies to identify what can be done to rectify any remaining issues.

If significant project modifications are needed, or if further construction actions are needed, the non-federal sponsors will work with the Corps and agency partners to identify the correct funding source. The non-federal sponsors could choose to take action and modify the project, or implement further mitigation on their own. They also could work with the Corps to secure potential funds under the Corps' Continuing Authorities Program (CAP) to modify an existing project. It also could include seeking congressional action to secure additional federal funds.

6.0 PUBLIC INVOLVEMENT, REVIEW AND CONSULTATION*

6.1 PUBLIC INVOLVEMENT PROGRAM

This chapter describes public involvement activities, agency consultation and coordination, and acknowledges the agencies that have been involved with this NEPA process.

6.1.1 Scoping Notice

A scoping notice was prepared to provide the public with information on the project and an opportunity for people to express their thoughts and comments. The notice announced the intent to prepare an Environmental Impact Statement and was published in the May 5, 2009, *Federal Register* Volume 74, Number 85. Maps showing locations of the project area and alternative features were made available for inspection. Dates and locations of public scoping meetings were identified in the notice. A scoping notice for the Supplemental Environmental Impact Statement was published in the December 27, 2010, *Federal Register* Volume 75, Number 247. Comments received during the scoping phase can be found in Appendix Q.

6.1.2 Public and Agency Scoping Meetings

The intent of the scoping meetings was to inform people about the project and to collectively identify key issues. The *Federal Register* notice and news releases to local media announced a series of public meetings. The locations and dates for these meetings were:

Table 64 – Public and Agency Scoping Meetings

Location	Date	Time	Attendees	Meeting Location
Moorhead , MN (Public)	November 17, 2008	7:00 p.m.	50	City Council Chambers
Fargo, ND (Public)	November 18, 2008	7:00 p.m.	40	Prairie Rose Inn
Fargo, ND (Public)	May 19, 2009	5:30 p.m.	115	The Centennial Hall, Fargo N.D.
Fargo, ND (Agency)	May 20, 2009	10:00 a.m.	44	The Centennial Hall, Fargo N.D
Moorhead, MN (Public)	May 20, 2009	5:30 p.m.	140	Hanson Theatre, University of Minnesota Moorhead Campus, MN

Several written comments were received in response to the public scoping effort. Several additional comments were received in response to the agency scoping effort. All comments have been reviewed and compiled in a scoping document which is included in Appendix F. The scoping document summarizes, consolidates, and organizes the public and agency comments.

6.1.3 Public Meetings

In addition to the public scoping meetings, public meetings were held to keep the public informed on the project and the path forward. These meetings were used to present the public with information and to gather feedback. The dates and locations of the public meetings are presented in Table 65. Presentations, handouts, and other general information from the meetings can be found in Appendix Q, Public Involvement and Coordination. The non-federal sponsors developed the Metro Flood Management Committee (MFMC) which consisted of all members from the Fargo City Council, Moorhead City Council, Clay County Board, and Cass County Board. As a subset to the MFMC a working group was developed consisting of members from the MFMC. The working group had a number of meetings that were open to the public and the Corps provided information and presentations at each of these meetings. The working group meetings were held on: August 26, 2009; November 5, 2009; November 12, 2009; December 17, 2009; January 15, 2010; February 4, 2010; February 11, 2010; February 18, 2010; February 25, 2010; March 4, 2010; March 11, 2010; March 18, 2010; April 22, 2010; April 25, 2010; May 13, 2010; May 26, 2010; August 5, 2010; August 25, 2010; November 18, 2010; December 9, 2010; January 13, 2011; January 19, 2011; February 24, 2011, April 1, 2011, May 12, 2011, May 26, 2011, and June 23, 2011.

Table 65 – Public Meetings

Location	Date	Time	Attendees*	Meeting Location
Moorhead, MN (MFMC)	October 19, 2009	8:00 a.m.	100	Marriott Hotel, Moorhead MN
Fargo, ND (Public)	October 20, 2009	6:00 p.m.	400	Howard Johnson Inn, Fargo ND
Moorhead, MN (Public)	October 21, 2009	6:00 p.m.	400	Hagan Hall, University of Minnesota Moorhead Campus, MN
Fargo, ND (MFMC)	November 24, 2009	7:30 a.m.	100	Ramada Plaza Suites, Fargo ND
Fargo, ND (MFMC)	February 1, 2010	11:00 a.m.	200	The Centennial Hall, Fargo ND
Fargo, ND (Public)	February 2, 2010	6:00 p.m.	400	The Centennial Hall, Fargo ND
Moorhead, MN (Public)	February 3, 2010	6:00 p.m.	200	Hanson Theatre, University of Minnesota Moorhead Campus, MN
Moorhead, MN (Public)	June 9, 2010	6:00 p.m.	60	Minnesota Moorhead Campus, Student Ballroom, MN
Fargo, ND (Public)	June 10, 2010	6:00 p.m.	50	The Centennial Hall, Fargo ND
Fargo, ND (Landowner)	June 14, 2010	6:00 p.m.	80	The Centennial Hall, Fargo ND
Moorhead, MN (Landowner)	June 15, 2010	6:00 p.m.	50	The Hjemkomst Center, Moorhead MN
Hendrum, MN (Downstream stakeholder)	June 16, 2010	6:00 p.m.	200	Hendrum Civic Center, Hendrum MN

Kindred, ND (Upstream stakeholder)	March 30, 2011	6:00 p.m.	400	Kindred High School, Kindred ND
West Fargo, ND (Public)	March 31, 2011	6:30 p.m.	200	West Fargo High School, West Fargo ND
Fargo, ND (Upstream Stakeholders)	December 9, 2010	7:00 p.m.	200	Bennett Elementary School, Fargo ND
Wahpeton, ND (Wilkin and Richland County Commissions)	May 3, 2011	1:00 p.m.	50	North Dakota State College of Science, Wahpeton ND
Comstock, MN (Public)	May 3, 2011	4:00 p.m.	75	Comstock Community Center, Comstock MN
Fargo, ND (Public)	May 23, 2011	6:00 p.m	50	Centennial Hall, Fargo ND
Kindred, ND (Public)	May 24, 2011	6:00 p.m	350	Kindred High School, Kindred ND
Moorhead, MN (Public)	May 25, 2011	6:00 p.m	80	Courtyard Marriott, Moorhead MN
Hendrum, MN (Public)	May 26, 2011	6:30 p.m.	80	Norman County West Elementary School, Hendrum MN
Fargo, ND (404(b)(1) Public Hearing)	June 1, 2011	7:00 p.m.	26	Centennial Hall, Fargo ND

*Approximate

6.1.4 Website

A website (http://www.internationalwaterinstitute.org/feasibility/index.htm) was established as the project's primary website. The purpose of the site was to deliver information to the public that was made available at public meetings and for distribution of information as part of the NEPA process. The website also provides the interested public opportunities to ask questions, submit comments through e-mail, or be added to an email mailing list. The Corps standard webpage is a secondary site which is used to distribute information. This site is located at: http://www.mvp.usace.army.mil/fl_damage_reduct/default.asp?pageid=907. In addition to the two project websites, the City of Moorhead provided live video of the February 3, 2010 meetings on its webpage.

6.2 RESOURCE AGENCY TEAM

The Corps established a resource agency team to facilitate transfer of information among agencies and between the agencies and the Corps through meetings and frequent communications at key steps of the process. The resource agencies provided information on their special expertise or jurisdiction related to the project, assisted with analyses, and reviewed draft report chapters and analyses. The following organizations participated during the process:

- Minnesota Department of Natural Resources (MDNR)
- Minnesota Pollution Control Agency (MPCA)
- U.S. Fish and Wildlife Service (USFWS)
- Environmental Protection Agency (EPA)
- North Dakota Game & Fish Department (NDGFD)
- Fargo-Moorhead Metropolitan Council of Governments (FM COG)
- North Dakota State Water Commission (ND SWC)
- North Dakota Department of Health
- Federal Emergency Management Agency (FEMA)
- North Dakota Wildlife Federation
- Buffalo Red River Watershed District (BRRWD)
- Cass County, North Dakota
- Clay County, Minnesota
- Southeast Cass Water Resources District (SE Cass WRD)
- Federal Aviation Administration (FAA)
- Minnesota Natural Resource Conservation Service (MN NRCS)
- North Dakota Natural Resource Conservation Service (ND NRCS)
- National Wildlife Federation (NWF)
- Minnesota Board of Water and Soil Resources (BWSR)
- Minnesota Department of Transportation (MNDOT)
- North Dakota Natural Resources Trust

Resource Agency Team meetings were held on the following dates and at the following locations:

- May 20, 2009 Fargo, North Dakota (scoping document)
- September 2, 2009 Fargo, North Dakota
- October 29, 2009 Fargo, North Dakota
- November 10, 2009 Fargo, North Dakota
- December 10, 2009 Fergus Falls, Minnesota
- December 22, 2009 St. Paul, Minnesota (conference call)
- February 3, 2010 Fargo, North Dakota
- February 19, 2010 Fargo, North Dakota
- April 22, 2010 Fargo, North Dakota
- May 12, 2010 St. Paul, Minnesota (conference call)
- June 10, 2010 Fargo, North Dakota
- June 28, 2010 Washington, D.C.
- July 12, 2010 St. Paul, Minnesota
- July 28, 2010 St. Paul, Minnesota (conference call)
- November 18, 2010 Fargo, North Dakota
- January 13, 2011 Fargo, North Dakota

- January 26, 2011 St. Paul, Minnesota (conference call)
- March 3, 2011 St. Paul, Minnesota (conference call)
- March 10, 2011 Fargo, North Dakota
- May 25, 2011 Fargo, North Dakota

Meeting notes can be found in Appendix F.

6.3 INSTITUTIONAL INVOLVEMENT

The non-federal sponsors for this study are the City of Fargo, North Dakota and the City of Moorhead, Minnesota. The cities have been supported and have received input during the study from the Southeast Cass Water Resource District, Cass County, the Buffalo-Red Watershed District, and Clay County. The sponsors have worked closely with the other local entities to develop a consensus on the path forward including the optimal levels of protection afforded by the project, the desire for a locally preferred plan, identifying which entities will be responsible for signing the Project Partnership Agreement with the Corps, and discussions on setting up a special joint powers agreement to address the non-federal cost-share and responsibilities. Recommendations on these topics were made by the Metro Flood Management Committee, and forwarded to each of the individual entities for formal adoption and approval.

6.4 ADDITIONAL REQUIRED COORDINATION

6.4.1 Coordination with Minnesota and North Dakota State Historic Preservation Office, the Advisory Council, and Other Interested Parties

A Programmatic Agreement has been negotiated between the St. Paul District, U.S. Army Corps of Engineers, the Minnesota State Historic Preservation Officer, and the North Dakota State Historic Preservation Officer. The City of Fargo and the City of Moorhead, the non-federal sponsors of the project, are concurring parties to the Programmatic Agreement. The Cass County (North Dakota) and Clay County (Minnesota) Boards of Commissioners and sixteen Indian tribes (see 6.4.1.1) were also invited to be concurring parties to the Programmatic Agreeement. The Programmatic Agreement covers the Corps' responsibilities to ensure compliance with Section 106 of the National Historic Preservation Act (NHPA), as amended, and its implementing regulations, 36 CFR Part 800, Protection of Historic Properties. Stipulations in the Programmatic Agreement provide for the continued consultation with these parties during historic preservation activities covered by the agreement. The Advisory Council on Historic Preservation was contacted by letter dated May 29, 2009, requesting their participation in the Programmatic Agreement for this Project. In an email response dated June 17, 2009, the Advisory Council declined to become involved in this project.

6.4.1.1 Coordination with Indian Tribes

Indian tribes with historic connections to the project area include the Sisseton Wahpeton Oyate of the Lake Traverse Reservation, the White Earth Band of Minnesota Chippewa, the Leech Lake Band of Ojibwe, the Turtle Mountain Band of Chippewa, the Upper Sioux Community of Minnesota, the Lower Sioux Indian Community, the Spirit Lake Tribe of North Dakota, and the Red Lake Band of Chippewa Indians. Additional tribes contacted included the Bois Forte Band of Chippewa Indians, the Three Affiliated Tribes (Mandan, Hidatsa and Arikara Nation), the Northern Cheyenne Tribe, the Standing Rock Sioux Tribe, the Yankton Sioux Tribe, the

Assiniboine and Sioux Tribes of the Fort Peck Indian Reservation, the Crow Creek Sioux Tribe and the Flandreau Santee Sioux Tribe. Highlights of consultation with tribes are given below.

April 8, 2009 – An initial contact letter was sent from the St. Paul District's District Engineer to tribal chairpersons of Sisseton Wahpeton, White Earth, Leech Lake, Turtle Mountain, Upper Sioux, Lower Sioux, Spirit Lake, and Red Lake tribes to determine if they wished to consult under Section 106 of the National Historic Preservation Act, as amended, regarding effects of the project on properties of traditional cultural or religious importance to them. A copy of the signed letter to the tribal chairperson was also furnished to each tribe's Tribal Historic Preservation Officer (THPO) or designated cultural resources point of contact (POC). Any consulting tribe may also be a concurring party to the Project's NHPA Programmatic Agreement.

May 1, 2009 – The THPO for the Leech Lake Band of Ojibwe responded that the Leech Lake Band did not have any concerns regarding cultural or religious sites in the project area.

June 2010 – The DEIS was sent to White Earth, Turtle Mountain, Upper Sioux, Lower Sioux, Spirit Lake and Red Lake tribes. Comments were due August 9, 2010.

August 9, 2010 – The Corps had a phone conversation with the Section 106 Coordinator at Sisseton Wahpeton THPO's office to set up a meeting to initiate consultation on the Project.

August 31, 2010 – Meeting at Sisseton Wahpeton THPO office in Sisseton, South Dakota. The Corps project manager, tribal facilitator and archeologist and Sisseton-Wahpeton THPO, Section 106 Coordinator and tribal archeologist met in person. The White Earth THPO, Bois Forte THPO, Yankton Sioux THPO, Leech Lake Heritage Sites, and City of Fargo participated in the meeting by phone. During the meeting, participants discussed a group tribal meeting, tribal input into Programmatic Agreement, tribal participation in surveys, and paying tribes travel per diem. Participants set a tentative meeting date for October 19, 2010.

October 7, 2010 – Letters were sent by certified mail from the Corps' District Engineer to tribal chairpersons with copies furnished with attachments to the THPOs and Cultural Resources POCs summarizing the August 31st meeting. The letters offered face-to-face group meeting or individual meetings, but noted that the District will not pay per diem for travel. Attachments included the revised Programmatic Agreement and North Dakota diversion and Minnesota diversion maps. Letters were sent to Sisseton Wahpeton, White Earth, Leech Lake, Yankton Sioux, Bois Forte, Turtle Mountain, Upper Sioux, Lower Sioux, Spirit Lake, Red Lake, Fort Peck, Three Affiliated Tribes, Northern Cheyenne, and Standing Rock.

December 3 to 16, 2010 – The Corps followed up the October 7 letters with telephone calls to THPOs and Cultural Resources POCs. The Red Lake Band stated that no further contact was needed. The Turtle Mountain, Leech Lake, and Lower Sioux stated that they did not want to meet but would like to be kept informed. The White Earth, Bois Forte, Standing Rock, Sisseton Wahpeton, Spirit Lake, and Fort Peck stated that they wished to meet face-to-face. The Three Affiliated Tribes, Northern Cheyenne, Upper Sioux, and Yankton Sioux did not respond.

December 21, 2010 – The Corps sent an email to THPOs and Cultural Resources POCs of the White Earth, Bois Forte, Standing Rock, Sisseton Wahpeton, Fort Peck, Spirit Lake, Northern Cheyenne, Yankton Sioux and Lower Sioux. The email stated that a face to face meeting would be held at Fargo on January 11, 2011 but that the District will not pay travel per diem.

January 7, 2011 – The Corps emailed the meeting agenda and telephone call-in number for the January 11, 2011 meeting.

January 11, 2011 – A face to face meeting with teleconference call-in was held at Fargo. The Standing Rock tribal historian and Fort Peck cultural resources director attended in person, along with the Corps project manager, tribal facilitator and archeologist and Fargo staff from the engineering department. The White Earth THPO and Bois Forte THPO participated by phone. The following handouts were provided: an agenda, power point presentation on Fargo Moorhead Metro Flood Risk Management Project, draft Programmatic Agreement (January 2011 version), air photos and topographic maps of North Dakota and Minnesota diversion alignments, URS cultural resources survey field reports #1 and #2, and photographs of river crossings.

January 28, 2011 – Paper copies of the DEIS were mailed to the Sisseton Wahpeton THPO, Fort Peck Cultural Resources Director, and Standing Rock THPO.

February 1, 2011 – The Corps emailed the January 11th meeting notes to the tribes. Paper copies of revised North Dakota diversion alignment air photos and topographic maps were mailed to the same tribes.

April 26, 2011 – A Traditional Cultural Properties Study contract for the Fargo-Moorhead Metro Flood Risk Management Project was negotiated with and awarded to the Turtle Mountain Band of Chippewa's Tribal Historic Preservation Office. None of the other tribes contacted had the ability to conduct this study under contract with the Corps.

May 12, 2011 – The Traditional Cultural Properties (TCP) Study kick-off meeting at Fargo was hosted by the Corps and the Turtle Mountain Band of Chippewa THPO. The Turtle Mountain and Standing Rock Sioux tribes were the only tribal representatives present. After a project overview presented by the Corps, meeting attendees discussed the draft Programmatic Agreement for the project and what language the tribes wanted to see included. Then, the Corps led a discussion using aerial photos of the diversion alignment to determine which areas along the proposed diversion alignment needed to be looked at during the follow-up field visit.

June 1-2, 2011 – The TCP Field Survey was held with representatives from the Corps, the Turtle Mountain Band of Chippewa, the Crow Creek Sioux Tribe, and the Flandreau Santee Sioux Tribe present. Several river crossing areas were walked and the remainder of the alignment driven. No TCPs were located in the project area. The draft TCP Study report is due July 20, 2011.

July 8, 2011 – The final version of the Programmatic Agreement for the Fargo-Moorhead Metro Flood Risk Management Project was mailed to the tribal chairperson of the Indian tribes for their signature as a concurring party to the agreement. Copies of these letters and the final agreement were also sent to the respective Tribal Historic Preservation Officers or Cultural Resources Point-of-Contact for their information.

6.4.1.2 Future Coordination with Agencies
The Corps and the non-federal sponsors will work with the following agencies to pursue authorities and funding to assist in the implementation of the proposed project:

- Federal Emergency Management Agency (FEMA)
- Minnesota Department of Transportation (MNDOT)
- Natural Resources Conservation Service (NRCS)
- North Dakota Department of Transportation (NDDOT)
- Federal Highway Administration (FHA)

An interagency Adaptive Management Team (AMT) is being developed to support this process. The roots of the AMT will form from the continued interagency coordination that has occurred throughout the process. This team will continue to meet to discuss the mitigation plans, pre- and post monitoring, and the adaptive management plan as we continue through the process. The team will generally consist of the resource agency team members.

6.5 REPORT RECIPIENTS

The following Federal, State, County, local and regional agencies, environmental organizations, and interested groups will receive notice of availability of this document:

- Red River Basin Commission (RRBC)
- International Red River Board (IRRB)
- Red River Watershed Management Board (RRWMB)
- North Dakota Red River Joint Water Resource District (NDJWRD)
- Minnesota Department of Natural Resources (MDNR)
- Minnesota Pollution Control Agency (MPCA)
- U.S. Fish and Wildlife Service (USFWS)
- Environmental Protection Agency (EPA)
- North Dakota Game & Fish Department (NDGFD)
- Fargo-Moorhead Metropolitan Council of Governments (FM COG)
- North Dakota State Water Commission (ND SWC)
- North Dakota Department of Health
- Federal Emergency Management Agency (FEMA)
- North Dakota Wildlife Federation
- Buffalo Red River Watershed District (BRRWD)
- Cass County, North Dakota
- Clay County, Minnesota
- Southeast Cass Water Resources District (SE Cass WRD)
- Federal Aviation Administration (FAA)

- Minnesota Natural Resource Conservation Service (MN NRCS)
- North Dakota Natural Resource Conservation Service (ND NRCS)
- National Wildlife Federation (NWF)
- Minnesota Board of Water and Soil Resources (BWSR)
- Indian Tribes with Historic Connections to project area

6.6 PUBLIC VIEWS AND RESPONSES

A complete list of public comments and responses regarding the scoping process is contained in Section 1.11 of Appendix F, Environmental. A complete list of public and private comments regarding the Draft Environmental Impact Statement is contained in Appendix R, Draft Environmental Impact Statement Public and Private Comments Received. Responses to the comments received are contained in Appendix S, Draft Environmental Impact Statement Public and Private Summarized Comments and Corps Responses. A complete list of public and private comments regarding the Supplemental Draft Environmental Impact Statement is contained in Appendix T, Supplemental Draft Environmental Impact Statement Public and Private Comments Received. Responses to the comments received are contained in Appendix U, Supplemental Draft Environmental Impact Statement Public and Private Summarized Comments and Corps Responses.

6.7 AGENCY CORRESPONDENCE

Agency correspondence and communications are included in Appendix Q, Public Involvement and Coordination. The correspondence included in Appendix Q only includes the correspondence that occurred after the Scoping Document was completed; the earlier correspondence can be found in section 1.11 of Appendix F.

6.7.1 Status of Environmental Coordination Activities

The Corps has had a number of meetings with the resource agencies as described in section 6.2. The coordination is an ongoing activity that will continue throughout the design and implementation of the selected plan. An indication of Section 401 Water Quality Certification was requested from both the Minnesota Pollution Control Agency (MPCA) and the North Dakota Department of Health. The MPCA indicated the request for Section 401 Water Quality Certification for this project should be submitted to the MPCA after the plans and specifications are prepared and that Section 401 Water Quality Certification would be considered at that time. No outstanding major water quality issues were identified by the MPCA. The North Dakota Department of Health indicated that there are no identified major issues at this time that would preclude Section 401 Water Quality Certification as the project proceeds.

6.7.2 Resource Agency Views

The views of the resource agencies can be found in Appendix R, Draft Environmental Impact Statement Public and Private Comments Received and Appendix T, Supplemental Draft Environmental Impact Statement Public and Private Comments Received.

6.8 RECOMMENDATIONS FROM THE FISH AND WILDLIFE COORDINATION ACT REPORT

Recommendations from the April 2011 Fish and Wildlife Coordination Act Report are responded to below. There were no new recommendations in the Final Fish and Wildlife Coordination Act Report dated July 2011 (see attachment 2). The Fish and Wildlife Service summarized the Corps' responses in its Final Report.

1. Determine wetland acreage to be impacted directly or indirectly by the proposed project, and assess the functions and values of individual wetlands with an established method of assessment, such as the Minnesota Rapid Assessment Method (MnRAM).

   Response: A team of Corps wetland scientists assessed wetlands using off-site review methodology, followed by field review to ground-truth the off-site review and to perform representative wetland delineations and functional assessments. Wetland areas were identified using all available sources of information, including National Wetlands Inventory (NWI) mapping, soil survey mapping, USGS topographic maps, LiDAR imagery and multiple years of aerial photography. Antecedent precipitation was analyzed prior to each field review, as well as in relation to dates of aerial photography.

   On July 1-2, 2010, the team reviewed both diversion corridor alignments to ground-truth the images and signatures identified on aerial photography as wetland areas. Antecedent precipitation for this field review was normal. Following this ground-truthing field review, the team completed the off-site mapping of all the wetlands within the study area. On July 27-30, 2010, the team returned to the study area to complete representative delineations and functional assessments, using the Corps of Engineers Wetland Delineation Manual (Manual), the Regional Supplement to the Corps Delineation Manual: Great Plains Region (Version 2.0), March 2010 (Supplement) and Minnesota Routine Assessment Methodology for Evaluating Wetland Functions (MnRAM), Version 3.3, refining the extent of wetlands within all off-site mapped areas. Antecedent precipitation prior to the final field review at the end of July 2010 was wet. The field work is documented in the "Fargo-Moorhead Metropolitan Area Feasibility Study Wetland Delineation Report" that is in Appendix F.

2. Provide compensatory mitigation for all wetland impacts in accordance with the standards specified for a Section 404 Permit under the Clean Water Act. A final wetland mitigation plan should be coordinated with the Service and Corps Regulatory Project Manager.

   Response: Design of the diversion channel alternatives, to include a sinuous low-flow channel, provides a number of self-mitigating factors to offset the loss of wetlands on the landscape due to the project itself. The diversion channel alternatives have the opportunity to return many of these functions back to the landscape in the area. Creating and restoring wetlands within the diversion footprint will increase the retention and treatment of flood/stormwater on the landscape, rather than moving it off the landscape as quickly as possible. Wetlands within the diversion, no longer subject to regular farming, will reestablish natural vegetation that will treat the water quality within the wetland, resulting in improved downstream water quality. This natural vegetation will also improve wildlife habitat in the area, providing refuge for wildlife and increasing diversity of species seen in the area.

For the FCP, ND35K, and the LPP the diversion channel itself is expected to provide a functional offset for the project impacts; approximately 1,515 acres (FCP), 1,527 acres (ND35K) and 1,450 acres (LPP) of wetlandsare expected to be established within the diversion corridor, including areas of seasonally flooded basin, wet meadow and shallow marsh. Additional prairie type habitat will be established within the diversion channel side slopes. This return of functionality to the landscape within the diversion corridor serves as self-mitigation to compensate for the impacts to wetland resources due to the project. (Note: Floodplain forest wetlands were assessed under a separate portion of this document, where mitigation for all forested resources will be provided at a ratio of 2:1. Forested communities take longer to become established than non-forested communities, resulting in a period of time between the loss of the existing forested resource and the return of a forested community. This is referred to as temporal loss of function from the forested resource. The mitigation ratio for forested communities partly accounts for this temporal loss.)

3. Wetlands within the currently active floodplains of the Red, Wild Rice (ND), Sheyenne, Lower Rush, and Rush Rivers, downstream of the proposed structures and the diversion channel crossings or channel abandonments should be monitored for a 10 year period following the beginning of project flood reduction operations. This monitoring should focus on hydrologic impacts to the wetlands, wetland type conversions, and loss of wetlands. (All Alternatives as appropriate)

   Response: The existing wetlands will not be adversely impacted by the project features because the more frequent event flows will be passing through the project the same as for existing conditions. For the Red River and the Wild Rice River the project will not start holding water back until the velocities reach 9,600 cfs, which is equivalent to a 28-percent chance event, meaning all lesser flows will pass as normal. These more frequent flows, along with precipitation, are what sustain the wetlands.

4. Utilize the data provided by the proposed geomorphic and biotic surveys within the potentially affected reaches of Red, Wild Rice (ND), Sheyenne, Maple, Lower Rush, and Rush Rivers to assess the quality of existing habitats and quantify impacts to the fish and wildlife resources.

   Response: Concur. This data was not available in time for the Final EIS. Impact quantification is based on the best data currently available. However, as a part of adaptive management, this new data collected will be used as the pre-project baseline to verify resulting impacts following project construction. These impacts will then be compared to mitigation effectiveness to verify that impacts have been negated.

5. Utilize native plant species in all aspects of mitigation, reconstruction, and replanting involved with the project.

   Response: Native plant species will be used for project mitigation as well as for reseeding excavated areas that result from project construction.

6. Avoid impacts to migratory bird nesting habitats (woodlands, grasslands, and wetlands) during the primary nesting season, April 1st to August 31st, to the greatest extent that is feasible.

   Response: Typical migratory bird species that are present in the project area include two special status species for North Dakota, the Northern Cardinal and the Whip-poor-wil, as well as many other breeding populations of bird species (Table 5 in Attachment 2 provides a complete list of Breeding Birds of Clay County, MN).

   Habitat used for nesting by migratory bird species may be disturbed or removed during project construction. To the extent practicable, vegetation clearing activities would be done so as to avoid affecting nesting individuals. Nonetheless, some limited take of individuals may occur incidental to construction activities. It is expected that any limited take would have no long lasting effect on the affected migratory bird species.

7. Provide equal mitigation (1:1) for lands currently enrolled in state or federally funded restoration or conservation programs that will be impacted by the proposed project.

   Response: Impacts to lands enrolled in state or federally funded restoration or conservation programs adversely will be mitigated. Currently none of these land types have been identified as being impacted by project construction or operation.

8. Raptor nest surveys should be conducted every spring to determine the presence of existing or new nests that may be affected by the project construction and excavation activities. Surveys should be completed annually prior to "leaf out" until the project construction is complete.

   Response: Concur. Raptor nest surveys will be conducted in early spring each year during construction in the areas where construction is ongoing, until construction is complete.

9. Follow the Service's National Bald Eagle Management Guidelines to minimize the likelihood that the proposed project will affect any bald eagles nesting in the Fargo/Moorhead Project Area.

   Response: Concur. The National Bald Eagle Management Guidelines will be followed to minimize the likelihood of project impacts to bald eagles nesting in the project study area.

10. Allocate funding toward and coordinate with the Service to develop large scale wetland restoration areas within the upstream reaches of the Red River basin, which could help attenuate flood waters in the smaller more frequent storm events.

    Response: The Fargo-Moorhead diversion is being designed to address extremely large flood events in which wetland restoration would provide little additional benefit. Flood storage upstream could help reduce flows from smaller, more frequent flood events and might reduce the diversion's frequency of operation, but it would not affect the design of the diversion project features. The Corps of Engineers has two ongoing studies that could complete additional investigations of the benefits and costs of implementing large-scale wetland restoration in the upper watershed. Those studies are the Fargo-Moorhead Upstream Study and the Red River Basin Wide Feasibility Study. These studies have already started development of HEC-HMS and HEC-RAS models that could be used to determine some benefits of these possible restoration efforts, including the potential for upstream flood storage to reduce the frequency of operation of the Fargo-Moorhead diversion. Specific investigations related to restoration would need to be coordinated and supported by the non-federal sponsors for each of the projects.

11. A survey for blooming western prairie fringed orchids will be coordinated with the Service, and will be completed at the identified location within the upstream staging area in Richland County, ND.

    Response: Concur.

7.0 LIST OF PREPARERS*

Name	Discipline	Experience	Role in Preparing Report
Jonathan Sobiech	Environmental/Forester	9 years	EIS Preparation, Impact Assessment and Mitigation Planning
Elliott Stefanik	Environmental/Fisheries	13 years	Fisheries-related Impact assessment and Mitigation Planning
Craig Evans	Planner/Project Management	11 years discipline/24 years Corps	Main Report and Planning Appendix
Aaron Snyder	Planner/Project Management	8 years	Main Report and Planning Appendix
Byron Williams	Spatial Analysis and Map Preparation	11.5 years	Preparing Maps and Figures
Renee McGarvey	Landscape Architect	11 years	Recreational Plan
Mike Lesher	Hydraulic Engineer	32 years in discipline/33 years Corps	Hydraulic and Hydrology Appendix
Aaron Buesing	Hydraulic Engineer	20 years discipline/18 years Corps	Hydraulic and Hydrology Appendix
Corby Lewis	Hydraulic Engineer	8 years	Hydraulic and Hydrology Appendix
Eric Wittine	Structures Engineer	12 years	Structures
Tony Fares	Structures Engineer	21 years	Structures
Jeff Hansen	Cost Engineer	11 years discipline/29 years Corps	Cost Estimator
John Albrecht	Real Estate	31 years	Real Estate
Rodney Peterson	Real Estate	20 years discipline/2 years Corps	Real Estate Attorney
Virginia Gnabasik	Archeologist	27.5 years	Cultural/Historical Section
Rick Carlson	Economist	21 years	Economics/Social
Lance Awsumb	Economist	2 years	Economics
Jeff McGrath	Economist	31 years	Economics Appendix and Social - Economic input for EIS
Kevin Bluhm	Economist	25 years	Economics
Kurt Heckendorf	Geotechnical Engineering	8 years	Geotech
Terry Jorgenson	Engineering Geologist	27 years	Ground Water/Buffalo Aquifer Geotech Appendix
Edith Pang	Civil Engineer/Civil Layout	25 years	General Engineering
Grant Riddick	Geologist	25 years	Geologist
Miguel Wong	Geomorphology/Water Resources Engineer	17 years	Geomorphology/Sedimentation
Dan Reinartz	Hydrology	31 years discipline/38 years engineering	Hydrology
Chanel Kass	Hydrology	2 years	Hydrology

8.0 RECOMMENDATIONS

As District Engineer, I have considered the environmental, social, and economic effects, the engineering feasibility, and comments received from the other resource agencies, the non-federal sponsors, and the public, and have determined that the selected plan presented in this report is in the overall public interest and is technically sound, environmentally acceptable, and economically feasible. I recommend that the selected plan and associated features described in this report be authorized for implementation as a federal project.

The selected plan is the Locally Preferred Plan, which is a North Dakota diversion channel conveying 20,000 cfs, with storage and staging and appropriate mitigation measures, as generally described in this report. The plan includes flood risk management features including but not limited to a 36-mile diversion channel, approximately ten miles of tie-back levees, a control structure on the Red River of the North, a control structure on the Wild Rice River, two aqueduct tributary structures—one on the Sheyenne River and one on the Maple River, two tributary drop structures, one tributary control structure, a diversion inlet structure, 19 highway bridges, four railroad bridges, a storage area, upstream staging, measures to address local drainage impacts, and other appurtenant facilities, and primary recreation features including but not limited to multipurpose trails, restrooms, potable water, picnic facilities, parking areas, and landscaping and tree plantings. All new railroad bridges, modifications to existing railroad bridges, track modification and associated features will be cost-shared as part of the project construction costs. The total estimated first cost of the selected plan based on October 2011 price levels is $1,781,348,000, with the federal and non-federal shares of total first cost estimated at $801,542,000 and $979,806,000, respectively. The flood risk management features have an estimated total first cost of $1,745,033,000, with the federal and non-federal shares estimated at $783,384,000 and $961,649,000, respectively. The recreation features have an estimated total first cost of $36,315,000, with the federal and non-federal shares estimated at $18,157,500 and $18,157,500 respectively. The annual operation and maintenance costs are $3,631,000. The selected plan has an overall benefit-cost ratio of 1.76 and would provide in excess of 1-percent chance level of risk reduction for the Fargo-Moorhead Metro Area.

The project will modify three existing federal projects: the Rush River Channel Improvement project authorized by the Flood Control Acts of 1948 and 1950; the Lower Rush River Channel Improvement project authorized under provisions of Section 205 of the 1948 Flood Control Act, as amended; and the Sheyenne River project authorized by the 1986 Water Resources Development Act. The modifications to these projects will not impact their authorized purposes, however portions of these projects will be abandoned.

These recommendations are made with the provision that, prior to implementation, the non-federal sponsors will agree to comply with the following requirements:

Federal implementation of the selected plan would be subject to the non-federal sponsors agreeing to comply with applicable federal laws and policies, including but not limited to:

a. Provide a minimum of 35 percent, but not to exceed 50 percent of total FCP flood risk management costs as further specified below:

1. Provide 25 percent of design costs allocated by the Government to flood risk management in accordance with the terms of a design agreement entered into prior to commencement of design work for the flood risk management features;
2. Provide, during the first year of construction, any additional funds necessary to pay the full non-federal share of design costs allocated by the Government to flood risk management;
3. Provide, during construction, a contribution of funds equal to 5 percent of total FCP flood risk management costs;
4. Provide all lands, easements, and rights-of-way, including those required for relocations, the borrowing of material, and the disposal of dredged or excavated material; perform or ensure the performance of all relocations; and construct all improvements required on lands, easements, and rights-of-way to enable the disposal of dredged or excavated material all as determined by the Government to be required or to be necessary for the construction, operation, and maintenance of the flood risk management features;
5. Provide, during construction, any additional funds necessary to make its total contribution for flood risk management equal to at least 35 percent of total FCP flood risk management costs;
6. Provide 100 percent of all incremental costs of the Locally Preferred Plan.

b. Provide 50 percent of total recreation costs as further specified below:

1. Provide 25 percent of design costs allocated by the Government to recreation in accordance with the terms of a design agreement entered into prior to commencement of design work for the recreation features;
2. Provide, during the first year of construction, any additional funds necessary to pay the full non-federal share of design costs allocated by the Government to recreation;
3. Provide all lands, easements, and rights-of-way, including those required for relocations, the borrowing of material, and the disposal of dredged or excavated material; perform or ensure the performance of all relocations; and construct all improvements required on lands, easements, and rights-of-way to enable the disposal of dredged or excavated material all as determined by the Government to be required or to be necessary for the construction, operation, and maintenance of the recreation features;
4. Provide, during construction, any additional funds necessary to make its total contribution for recreation equal to 50 percent of total recreation costs;
5. Provide, during construction, 100 percent of the total recreation costs that exceed an amount equal to 10 percent of the Federal share of total FCP flood risk management costs;

c. Shall not use funds from other federal programs, including any non-federal contribution required as a matching share therefore, to meet any of the non-federal obligations for the project unless the federal agency providing the Federal portion of such funds verifies in writing that expenditure of such funds for such purpose is authorized;

d. Not less than once each year, inform affected interests of the extent of protection afforded by the flood risk management features;

e. Agree to participate in and comply with applicable Federal floodplain management and flood insurance programs;

f. Comply with Section 402 of the Water Resources Development Act of 1986, as amended (33 U.S.C. 701b-12), which requires a non-federal interest to prepare a floodplain management plan within one year after the date of signing a project cooperation agreement, and to implement such plan not later than one year after completion of construction of the flood risk management features;

g. Publicize floodplain information in the area concerned and provide this information to zoning and other regulatory agencies for their use in adopting regulations, or taking other actions, to prevent unwise future development and to ensure compatibility with protection levels provided by the flood risk management features;

h. Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) such as any new developments on project lands, easements, and rights-of-way or the addition of facilities which might reduce the level of protection the flood risk management features afford, hinder operation and maintenance of the project, or interfere with the project's proper function;

i. Keep the recreation features, and access roads, parking areas, and other associated public use facilities, open and available to all on equal terms;

j. Comply with all applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended (42 U.S.C. 4601-4655), and the Uniform Regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way required for construction, operation, and maintenance of the project, including those necessary for relocations, the borrowing of materials, or the disposal of dredged or excavated material; and inform all affected persons of applicable benefits, policies, and procedures in connection with said Act;

k. For so long as the project remains authorized, operate, maintain, repair, rehabilitate, and replace the project, or functional portions of the project, including any mitigation features, at no cost to the Federal Government, in a manner compatible with the project's authorized purposes and in accordance with applicable Federal and State laws and regulations and any specific directions prescribed by the Federal Government;

l. Give the Federal Government a right to enter, at reasonable times and in a reasonable manner, upon property that the non-Federal sponsor owns or controls for access to the project for the purpose of completing, inspecting, operating, maintaining, repairing, rehabilitating, or replacing the project;

m. Hold and save the United States free from all damages arising from the construction, operation, maintenance, repair, rehabilitation, and replacement of the project and any betterments, except for damages due to the fault or negligence of the United States or its contractors;

n. Keep and maintain books, records, documents, or other evidence pertaining to costs and expenses incurred pursuant to the project, for a minimum of 3 years after completion of the accounting for which such books, records, documents, or other evidence are required, to the extent and in such detail as will properly reflect total project costs, and in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and Local Governments at 32 Code of Federal Regulations (CFR) Section 33.20;

o. Comply with all applicable Federal and State laws and regulations, including, but not limited to: Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 U.S.C. 2000d) and Department of Defense Directive 5500.11 issued pursuant thereto; Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army"; and all applicable Federal labor standards requirements including, but not limited to, 40 U.S.C. 3141- 3148 and 40 U.S.C. 3701 – 3708 (revising, codifying and enacting without substantial change the provisions of the Davis-Bacon Act (formerly 40 U.S.C. 276a *et seq.*), the Contract Work Hours and Safety Standards Act (formerly 40 U.S.C. 327 *et seq.*), and the Copeland Anti-Kickback Act (formerly 40 U.S.C. 276c *et seq.*);

p. Perform, or ensure performance of, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Public Law 96-510, as amended (42 U.S.C. 9601-9675), that may exist in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project. However, for lands that the Federal Government determines to be subject to the navigation servitude, only the Federal Government shall perform such investigations unless the Federal Government provides the non-federal sponsors with prior specific written direction, in which case the non-federal sponsors shall perform such investigations in accordance with such written direction;

q. Assume, as between the Federal Government and the non-federal sponsors, complete financial responsibility for all necessary cleanup and response costs of any hazardous substances regulated under CERCLA that are located in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project;

r. Agree, as between the Federal Government and the non-federal sponsors, that the non-federal sponsors shall be considered the operator of the project for the purpose of CERCLA liability, and to the maximum extent practicable, operate, maintain, repair, rehabilitate, and replace the project in a manner that will not cause liability to arise under CERCLA; and

s. Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended (42 U.S.C. 1962d-5b), and Section 103(j) of the Water Resources Development Act of 1986, Public Law 99-662, as amended (33 U.S.C. 2213(j)), which provides that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until each non-federal interest has entered into a written agreement to furnish its required cooperation for the project or separable element.

This plan is being recommended with such modifications thereof as in the discretion of the Commander, HQUSACE, may be advisable.

The recommendation contained herein reflects the information available at this time and current departmental policies governing formulation of individual projects. It does not reflect program and budgeting priorities inherent in the formulation of a national civil works construction program nor the perspective of higher review levels within the executive branch. Consequently, the recommendation may be modified before it is transmitted to the Congress as a proposal for authorization and implementation funding. However, prior to transmittal to Congress, the non-federal sponsors, the State of Minnesota, the State of North Dakota, interested Federal agencies, and other parties will be advised of any modifications and will be afforded the opportunity to comment further.

Michael J. Price
Colonel, Corps of Engineers
District Engineer

Attachment 1

Fargo-Moorhead Metro

Final Feasibility Report and Environmental Impact Statement

July 2011

Section 404(b)(1) Evaluation

Attachment 1

Section 404(b)(1) Evaluation

SECTION 404(B)(1) EVALUATION
FARGO MOORHEAD METROPOLITAN
FLOOD RISK MANAGEMENT STUDY
CASS COUNTY, NORTH DAKOTA AND CLAY COUNTY, MINNESOTA

I PROJECT DESCRIPTION

A. Background – The U.S. Army Corps of Engineers (Corps) has prepared an integrated Feasibility Report and Environmental Impact Statement (Feasibility/EIS document) to present the results of its studies to address flooding problems in the Fargo Moorhead Metropolitan Area and describe possible consequences of implementing various alternatives. The geographic scope of analysis for the environmental impacts of the proposed action and alternatives encompasses the Fargo-Moorhead Metropolitan region plus areas in the floodplain of the Red River from approximately 300 river miles north of Fargo near Emerson, Manitoba to approximately 30 miles south of Fargo near Abercrombie, ND. The Fargo-Moorhead Metropolitan region is located within the area from approximately 12 miles west to 5 miles east of the Red River and from 20 miles north to 20 miles south of Interstate Highway 94. Fargo and Moorhead are on the west and east banks, respectively, of the Red River of the North which flows north approximately 453 river miles to the mouth of the river at Lake Winnipeg in Manitoba, Canada. The Fargo-Moorhead metropolitan area has a relatively high risk of flooding. Flooding in Fargo-Moorhead typically occurs in late March and early April as a result of spring snowmelt. Average annual flood damages in the Fargo-Moorhead metropolitan area are estimated to be over $194.8 million. The Red River of the North has exceeded the National Weather Service flood stage of 18 feet in 48 of the past 109 years, and every year from 1993 through 2011. In addition to the Red River, the Wild Rice River (North Dakota), Sheyenne River, Maple River, Lower Rush River and the Rush River contribute to the flooding issues in the study area.

The study analyzed a number of possible alternatives that could potentially achieve the original purpose and need identified for the feasibility study: reducing flood risk, flood damages and flood protection costs related to the flooding in the Fargo-Moorhead Metropolitan Area. These measures included: no action - continue emergency measures; nonstructural measures; flood barriers; increased conveyance; and flood storage. These alternatives are described in detail in sections 3.2 through 3.5 of the Feasibility/EIS document.

The alternatives went through an initial screening that used the following criteria: effectiveness, environmental effects, social effects, acceptability, implementability, cost, risk, separable mitigation, and cost-effectiveness. Initial screening results were presented in the Alternatives Screening Document dated December 2009 which is attached to Appendix O of the feasibility report. The rationale used in the screening process is also summarized in section 3.4 and 3.5 of the Feasibility/EIS document. The analysis resulted in two diversion concepts being carried forward: a diversion in Minnesota and a diversion in North Dakota. The diversion concepts significantly outperformed any other conceptual alternative with respect to achieving the stated purpose and need in a cost effective manner using existing technology.

Diversion capacities ranging from 10,000 cubic feet per second (cfs) to 45,000 cfs were analyzed for the Minnesota diversion alignment; capacities ranging from 20,000 through 35,000 cfs were analyzed for the North Dakota alignment. In addition, various features were looked at for the North Dakota alignment to minimize downstream impacts. The design, alignments, and features were refined, baseline cost estimates for each plan were completed, and an economic analysis was performed. The study identified a 40,000 cfs diversion along the Minnesota Short alignment as the national economic development (NED) plan, which maximizes national net average annual economic benefits. A Federally Comparable Plan (FCP) of a 35,000 cfs Minnesota diversion channel was designed to provide a comparison for cost-sharing purposes; benefits and impacts of the FCP are slightly smaller than those of the NED plan. While the Minnesota alignment was most cost effective from the Federal economic perspective, it did not reduce flood risk for the portion of the study area affected mainly by the Sheyenne River and its tributaries, the Maple, Rush and Lower Rush rivers.

The Federal objective in water resources planning is to contribute to NED. Corps of Engineers planning studies must comply with the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G). The P&G requires that the feasibility study must identify the plan that reasonably maximizes NED benefits consistent with protecting the environment (the NED plan). The NED plan must be recommended for implementation unless there are overriding reasons for recommending another plan, based on other Federal, state, local and international concerns. Corps of Engineers planning regulations recognize that it is appropriate to consider factors other than NED in selecting a plan for implementation, but the Corps relies on the NED analysis to determine the appropriate level of federal investment in the resulting project. The NED plan often fails to fully address the overall planning objectives, since it is defined and constrained primarily by cost effectiveness. Corps of Engineers regulations allow non-federal partners to identify a locally preferred plan and contribute additional funding to achieve objectives not met with the NED plan.

During the course of the planning process, it became evident that local stakeholders strongly desired measures to reduce flood risk for the entire Metropolitan area, including flooding from the Red River of the North, as well as the Sheyenne, Wild Rice (ND), Maple, Rush, and Lower Rush rivers. A locally preferred plan is the plan that, in the opinion of the non-federal sponsors, best meets the needs of the local community. Corps regulations allow recommendation of a LPP if the plan has a benefit to cost ratio greater than 1.0 and if a waiver to allow recommendation of the LPP is approved by the Assistant Secretary of the Army for Civil Works. A 35,000 cfs diversion along the North Dakota East alignment was identified as the locally preferred plan in the Draft Feasibility/EIS document. Upon further study of the North Dakota 35,000 cfs channel alternative

(ND35K) using current modeling, the Corps determined that it would have widespread adverse effects on infrastructure downstream and mitigation for these adverse effects is not logistically practicable. Therefore, the ND35K plan is not a practicable alternative.

Following further study of possible alternatives, the non-federal sponsors identified a 20,000 cfs diversion along the North Dakota East alignment, along with upstream storage and staging, as a locally preferred plan (LPP) that would reduce flood risk for both the Red River and the five tributaries. The cities of Fargo and Moorhead, Cass County, North Dakota, Cass County Joint Water Resource District, North Dakota, Clay County, Minnesota, and the Buffalo-Red River Watershed District, Minnesota jointly requested that the revised North Dakota plan be pursued as the LPP on April 6, 2011. The original request to designate the ND35K as an LPP for the Draft Feasibility/EIS document was approved by the Assistant Secretary of the Army for Civil Works (ASA(CW)) on April 28, 2010; the updated request for the revised LPP was approved by the (ASA(CW)) on April 28, 2011. The LPP provides flood stage reductions to a greater geographic area and for approximately 6,250 additional citizens than does the NED plan or FCP. It achieves this result by reducing flood risk from the Sheyenne River and its tributaries in addition to the Wild Rice (ND) and Red rivers. This added level of risk reduction is not available from the NED plan or FCP.

Various entities have raised the issue of why the purpose and need statement in the Feasibility/EIS document differs from the overall project purpose for the 404(b)(1) evaluation. The purpose and need for the Feasibility Study and Environmental Impact Statement was established prior to commencement of the study. At that time, a broad purpose and need was identified that would facilitate study of the flooding problems in the Metropolitan area and possible alternatives to manage the risk from the floods. The geographic scope of analysis in the scoping document for the NEPA process included the tributaries. As study of the flooding problems progressed, it became evident that flooding from the five tributaries significantly contributed to the problems experienced in the Metropolitan area. In order to achieve comprehensive flood risk management, a project that would address flooding on the five tributaries was needed. Providing protection from these additional sources within the basin is a legitimate purpose for the project, and is a project outcome that the non-federal sponsors of the project strongly support. The Corps is required to take account of the non-federal sponsors' desired outcomes in defining the overall project purpose in the context of the 404(b)(1) evaluation. It is not inconsistent to define the overall project purpose in the 404(b)(1) evaluation differently, and more specifically, than the purpose and need for the project in the NEPA analysis based on a consideration of the non-federal sponsors desired outcomes for the project. This approach is consistent with the Corps Standard Operating Procedures, which explain that the overall project purpose for the 404(b)(1) evaluation must consider the needs of project sponsors. Therefore, the overall project purpose for the Clean Water Act evaluation includes addressing flooding from the five tributaries, and alternatives failing to meet this purpose are not practicable. In summary, the purpose and need for the Feasibility Study and Environmental Impact Statement was a broad statement intended to facilitate study of the problem from a wide-ranging and general point of view. The overall project purpose identified for purposes of the Clean Water Act

Section 404(b)(1) Evaluation

Subsection 404(b)(1) analysis has been informed, clarified, and focused by that study and is therefore refined based on what was learned in that broader, earlier study.

This Section 404(b)(1) evaluation pertains to the LPP fully described in section 3.13 of the Feasibility/EIS document. The proposed project (i.e. the LPP) is the least environmentally damaging practicable alternative that would achieve the overall project purpose of reducing flood risk from both the Red River and the five North Dakota tributaries.

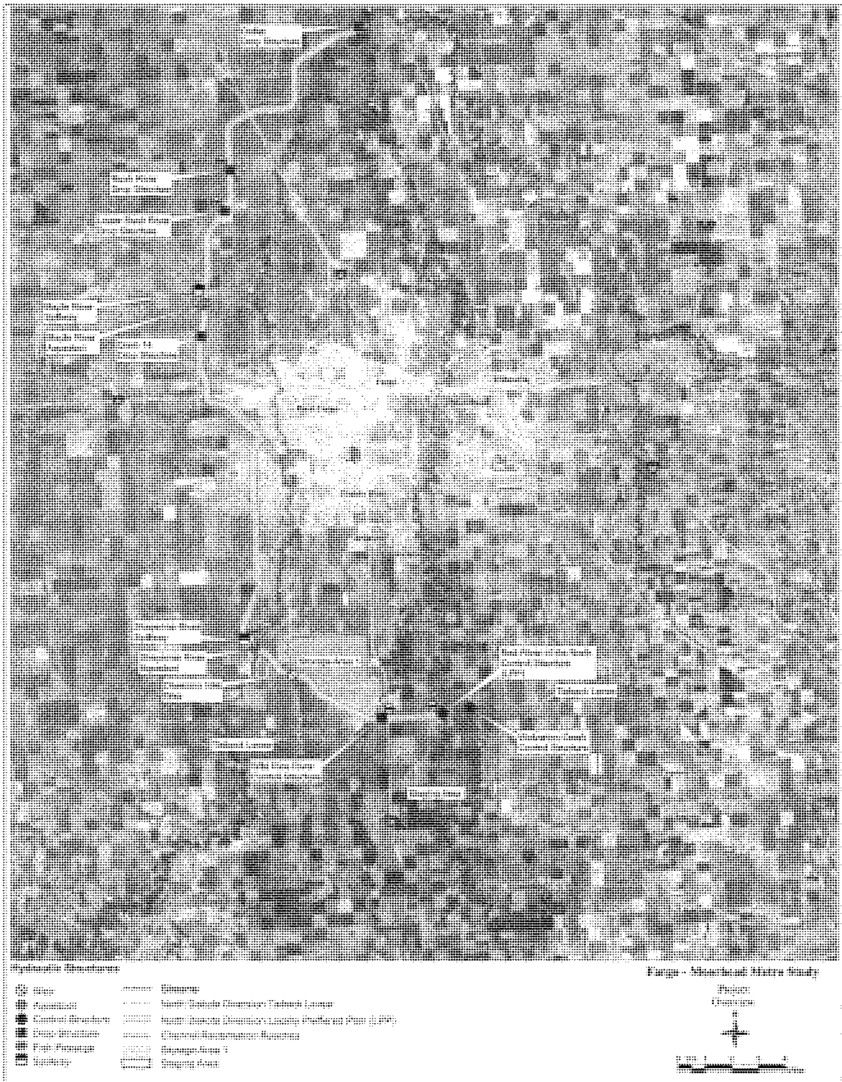
B. Location – The project area affected by the diversion construction is located in Cass County, North Dakota and Clay County, Minnesota. The proposed fill activities will take place in the Red River of the North, Wild Rice River, Sheyenne River, Maple River, Lower Rush River and the Rush River. Fill activities on the Red River are at three locations; at river mile 479 where the diversion channel is diverted away from the Red River, a little upstream of river mile 478 where the control structure is constructed, and at river mile 419 where the diversion channel would re-enter the main channel of the Red River (Figure 1). Fill activities would also occur in wetlands along the diversion alignment, the tie-back levees, and the storage area levee and at the general location of the hydraulic structures in the Wild Rice, Sheyenne, Maple, Rush and Lower Rush Rivers; these locations are shown on Figure 1.

C. General Description – This evaluation addresses the effects that would result from the placement of fill in waters of the United States in conjunction with the construction of a North Dakota diversion channel and the construction of hydraulic structures necessary for the operation of the diversion channel. The effects associated with the operation of the diversion channel and hydraulic structures are discussed in detail in chapter 5 of the Feasibility /EIS document. The diversion plan includes a 36 mile long diversion channel with a varying bottom width of 100 – 250 feet; the diversion channel would divert a portion of the Red River flow upstream of the metro area, pick up flow at the Wild Rice, Sheyenne, Maple, Lower Rush and Rush rivers, and return it to the Red River downstream of the Fargo Moorhead metro area. A control structure (Figure 16 of the Feasibility/EIS document) would be constructed adjacent to the Red River immediately downstream of the diversion inlet; once the control structure was built, the Red River would be re-routed through the control structure and back into the natural Red River channel. This structure would limit flows downstream in the natural channel and increase the efficiency of the diversion channel. The outlet structure located where the diversion returns to the Red River of the North would be an Ogee-type concrete spillway with a width of 250 feet. In addition, there would be hydraulic structures located at each tributary crossing. At the Wild Rice River crossing there would be two weirs and a control structure similar to the Red River control structure, also built in the dry. At the Maple River and Sheyenne River crossings there would be an open aqueduct that crosses over the top of the diversion channel and a weir spillway that would direct flows into the diversion channel (Figures 18-24 of the Feasibility/EIS document); these structures would also be built in the dry. At the Lower Rush River and Rush River, a stepped concrete spillway will be used to divert the entire flow into the diversion channel while abandoning the remaining channel between the diversion channel and the Sheyenne

River. A 4,400 acre flood water storage area surrounded by 12 miles of levee (Storage Area 1) would be constructed inside of the protected area northwest of the Wild Rice River control structure. Approximately 10 miles of tie-back levees would be constructed to connect the Red River control structure and the diversion inlet weir to high ground and prevent water from circumventing the project. A gated culvert structure would be constructed where Wolverton Creek crosses the tie-back levee east of the Red River. The project would go into effect when combined flows from the Wild Rice and Red River equal 9,600 cfs; at that time water would start pooling upstream of the Wild Rice and Red River control structures. Also at that time water would begin to enter into Storage Area 1. Depending on the size of the event, water could be staged as far as 10-15 miles up-stream with increase of depths varying from zero to 9 feet (Figure 1).

The proposed fill activities associated with the construction of the hydraulic structures, Storage Area 1, tie-back levees, and the excavation of the diversion channel will include: partially filling the abandoned channels; excavation for the diversion channel and sidecasting material into wetlands approximately 600 feet on either side of the diversion channel; placing fill into wetlands along the levee routes; placing riprap in the Red River where the diversion channel would re-enter the Red; and fill associated with diverting the flow through the constructed hydraulic structures.

Figure 1. LPP



D. Authority and Purpose – This study is authorized by a September 30, 1974, Resolution of the Senate Committee on Public Works. A Reconnaissance Report for the Fargo-Moorhead Metropolitan Area was approved by the Corps' Mississippi

Valley Division on April 8, 2008. Based on the recommendations contained in the Reconnaissance Report, the city of Fargo, North Dakota; the city of Moorhead, Minnesota, and the Federal Government entered into a Feasibility Cost Share Agreement on September 22, 2008. The feasibility study is cost shared 50/50 between the two non-federal sponsors and the Federal Government. As explained above, the refined overall project purpose is to reduce flood risk, flood damages and flood protection costs related to the flooding in the Fargo-Moorhead Metropolitan Area caused by the Red River of the North, as well as the Sheyenne, Wild Rice (ND), Maple, Rush, and Lower Rush rivers.

E. General Description of Dredged or Fill Material

1. General Characteristics of Material – Final determinations for the source of material have not been made. Rock for the project would be obtained from existing sources. Stone for riprap would be durable material free from cracks, blast fractures, bedding, seams and other defects that would tend to increase deterioration from natural causes. Bedding used for the base layer would be clean rock 8-inches in diameter, or smaller, produced from an existing facility. Levee fill would be obtained from project excavations.

2. Quantity of Material – For the purpose of this analysis quantities were calculated based on the ordinary high water mark (OHWM) being at the level of the 50-percent chance event. There would be approximately 715,600 cubic yards of earth fill placed below the OHWM, approximately 75,000 cubic yards of rip rap and aggregate filter fill placed below the OHWM, and 22,800 sf of sheet pile installed below the OHWM; Table 1 describes quantities for each area of impact. Geotextile fabric would be placed on river banks prior to stabilization with riprap for all hydraulic structure features. These quantities are based on the Phase 4 design as of February 28, 2011, and will need to be revisited and modified during detailed design. These numbers are also overstated slightly due to the fact that that the level of the 50-percent chance event is actually above the OHWM in many locations, but for consistency this parameter was used to calculate these quantities.

Table 1. Impacts

Impact Location: LPP	Estimated Impact Type	Estimated Impact Magnitude	Units
Red River Control Structure	Fill Within OHWM	20.5	acre
Red River Control Structure	Fill Volume Below OHWM	405,000	cy
Red River Control Structure	Excavation Within OHWM	2.2	acre
Red River Control Structure	Riprap and Aggregate Filter Fill Within OHWM	13,000	cy
Red River Control Structure	Sheet Pile Installed Within OHWM at Toe of Tie-back Levee Crossing	9,000	sf
Hydraulic Structure at Wild Rice River	Fill Within OHWM	10.1	acre
Hydraulic Structure at Wild Rice River	Fill Volume Below OHWM	113,000	cy
Hydraulic Structure at Wild Rice River	Excavation Within OHWM	0.9	acre
Hydraulic Structure at Wild Rice River	Wild Rice River Rock Boulder Grade Control with Aggregate Bedding Within OHWM	1.0	acre
Hydraulic Structure at Wild Rice River	Riprap and Aggregate Filter Fill Within OHWM	12,000	cy
Hydraulic Structure at Wild Rice River	Sheet Pile Installed Within OHWM at Toe of Fill	4,200	sf
Hydraulic Structure at Sheyenne River	Fill Within OHWM	4.4	acre
Hydraulic Structure at Sheyenne River	Fill Volume Below OHWM	66,000	cy
Hydraulic Structure at Sheyenne River	Excavation Within OHWM	1.9	acre
Hydraulic Structure at Sheyenne River	Sheyenne River Rock Boulder Grade Control with Aggregate Bedding Within OHWM	1.0	acre
Hydraulic Structure at Sheyenne River	Riprap and Aggregate Filter Fill Within OHWM	5,000	cy
Hydraulic Structure at Sheyenne River	Sheet Pile Installed Within OHWM at Toe of Fill	4,800	sf
Hydraulic Structure at Maple River	Fill Within OHWM	7.5	acre

Hydraulic Structure at Maple River	Fill Volume Below OHWM	70,000	cy
Hydraulic Structure at Maple River	Excavation Within OHWM	2.3	acre
Hydraulic Structure at Maple River	Maple River Rock Boulder Grade Control with Aggregate Bedding Within OHWM	1.0	acre
Hydraulic Structure at Maple River	Riprap and Aggregate Filter Fill Within OHWM	5,000	cy
Hydraulic Structure at Maple River	Sheet Pile Installed Within OHWM at Toe of Fill	4,800	sf
Hydraulic Structure at Lower Rush River	Fill Within OHWM	4.1	acre
Hydraulic Structure at Lower Rush River	Fill Volume Below OHWM	20,000	cy
Hydraulic Structure at Lower Rush River	Excavation Within OHWM	0.2	acre
Hydraulic Structure at Lower Rush River	Riprap and Aggregate Filter Fill Within OHWM	7,000	cy
Hydraulic Structure at Rush River	Fill Within OHWM	5.0	acre
Hydraulic Structure at Rush River	Fill Volume Below OHWM	40,000	cy
Hydraulic Structure at Rush River	Excavation Within OHWM	1.0	acre
Hydraulic Structure at Rush River	Riprap and Aggregate Filter Fill Within OHWM	7,000	cy
Diversion Outlet to Red River	Fill Within OHWM	12.0	acre
Diversion Outlet to Red River	Riprap and Aggregate Filter Fill Within OHWM	25,000	cy
Hydraulic Structure at Wolverton Creek	Fill Within OHWM	0.2	acre
Hydraulic Structure at Wolverton Creek	Fill Volume Below OHWM	1,600	cy
Hydraulic Structure at Wolverton Creek	Excavation Within OHWM	0.8	acre
Hydraulic Structure at Wolverton Creek	Excavate and Install Riprap Within OHWM	1,000	cy

Earthwork Estimates

Diversion Channel	Channel Stripping	3,197,320	cy
	Berm Stripping	5,942,000	cy
	Type 1 Excavation*	11,467,403	cy

	Type 2 Excavation**	13,011,929	cy
	Type 3 Excavation***	17,622,600	cy
	Type 4 Excavation****	3,660,415	cy
	Low Flow Channel Excavation	387,780	cy
	TOTAL EARTHWORK	55,289,447	cy
	Channel Topsoil (From Stockpile)	1,065,773	cy
	Berm Topsoil (From Stockpile)	7,944,499	cy
Storage Area 1 Levee Embankment			
	Topsoil Stripping	1,000,300	cy
	Excavation and Fill	3,200,000	cy
	Seeding	620	acre
Tie-back Levee - TBL East 2B	Topsoil Stripping	110,024	cy
	Excavation and Fill	835,320	cy
	Seeding	113	acre
Tie-back Levee - TBL Cass 17	Topsoil Stripping	68,739	cy
	Excavation and Fill	292,080	cy
	Seeding	74	acre

* Non-Saturated Non-Brenna Soil
** Saturated Non-Brenna Soil
*** Oxidized Brenna Soil
**** Brenna Soil

3. Source of Material - All stone would be clean and reasonably free from soil, quarry fines, and would contain no refuse. Materials would be obtained from approved pits/quarries in the project vicinity and would be free of chemical contaminants.

F. Description of the Proposed Discharge Sites

1. Location – For Red River control structure construction, material would be placed just upstream of river mile 478, but off to the side of the channel and would only have fill impacts when the channel gets diverted toward the structure; at these locations the channel would have to be filled to help divert the flow toward the structure. For the diversion outlet construction material would be placed between river miles 418 and 419 on the Red River across the 200 foot width of the river and approximately 500 feet length. For the diversion channel control structure, construction material would be placed into the Red River for approximately 200 feet just downstream of river mile 479 and also at the crossings of the Wild Rice, Sheyenne, Maple, Lower Rush and Rush rivers (Figure 1). Approximately 1,161 acres of wetlands would be filled or excavated along the diversion channel alignment, the route of the storage area levees, or the route of the tie-back levees.

2. Size - Approximately 14 acres of riverine habitat would be affected by the abandonment of river channel for the construction of the Red River control structure. Approximately two acres of riverine habitat on the Red River would be affected by fill activities for the construction of the diversion channel where it exits and re-enters the Red River. Approximately 1,161 acres of wetlands would be affected by either fill activities or excavation along the diversion channel route. Approximately 12 riverine acres at the Wild Rice River crossing, eight riverine acres at the Sheyenne River crossing, 10 riverine acres at the Maple River crossing, three riverine acres at the Lower Rush River crossing and three riverine acres at the Rush River crossing would be affected by the proposed fill activities. A total area of approximately 50 riverine acres and approximately 1,111 other wetland acres would be affected. A detailed description of these acreages with figures can be found in chapter 5 of the Feasibility/EIS document.

3. Type of Site/Type of Habitat – Habitat affected by the proposed fill activities is a mix of wet meadow, shallow marsh, shallow open water, floodplain forest, riverine habitat, and farmed seasonally flooded wetland. Farmed seasonally flooded wetlands constitute the vast majority of the affected acreage (795 acres). The aquatic habitats located within the project area are typical of the Red, Wild Rice, Sheyenne, Rush, Lower Rush and Maple rivers. Depths on the Red River and the tributaries generally vary from 1 to 2 feet near shoreline areas to about 5-20 feet at mid-channel locations, depending on the tributary. Substrates present include a mixture of silt, sand, and clay (see Geomorphology in Chapter 4 of the Feasibility/EIS document). The channel is approximately 200 feet wide in the vicinity of the Red River control structure and 20-80 feet wide at the other tributary crossings.

4. Timing and Duration - Subject to approvals and appropriation of funds, construction could potentially begin in the year 2013. Construction is expected to last approximately eight and a half years, if sufficient funding is appropriated.

G. Description of Disposal Method – Material would be moved and placed mechanically. Cranes, backhoes, scrapers, dump trucks and other heavy machinery suited to working with rock would be used to deliver and place rock materials and other levee fill during construction. Riprap would generally be placed in a systematic manner to ensure a continuous uniform layer of well-graded stone. Stone placed underwater would not be cast across the surface of the water.

II. FACTUAL DETERMINATIONS

A. Physical Substrate Determinations

1. Substrate Elevation and Slope - Substrate would be excavated before placement of riprap and aggregate filter layer(s) to ensure that the existing substrate grade is maintained. Riprap placed on slopes for erosion protection would follow the existing contour. An exception to this armoring technique would be at areas of significant water depth in existing channels, where armoring would be placed directly over existing grade

to avoid dredging below the water surface elevation. The areas where different armoring placement strategies are utilized will be determined during final design. At locations where channels are directed through newly constructed hydraulic structures, the substrate will consist of concrete at the locations of the hydraulic structures.

2. Sediment Type - Substrates in the Red River basin are composed primarily of clay rich, unconsolidated glacial sediments. Placement of riprap for erosion protection would replace existing substrates with multiple layers of rock with varying gradations.

3. Dredged/Fill Material Movement – Fill material will be placed directly into abandoned reaches of the river channels. The fill material will be sufficiently large or protected with riprap, sheetpile coffering, plant community restoration or other stabilization measures so as to preclude downstream movement of the placed material. The method of stabilization applied to specific areas will be determined during final design.

4. Actions Taken to Minimize Impacts - Standard construction procedures in compliance with Federal and State requirements and best management practices would be used during construction to minimize impacts. Work on the rivers would be done during low flow periods so as to limit downstream sedimentation. Construction sequencing will be used to minimize impacts. Construction of large hydraulic structures (at the Red, Wild Rice, Sheyenne and Maple Rivers) will take place off channel "in the dry" to avoid exposure of unprotected soils within the existing river channels during the construction of the structure. Following the structure's construction, these sites will be connected to the existing river channels with excavated channels. At this time, stabilization measures will be promptly applied to reduce the amount of downstream sedimentation. Temporary erosion prevention and sedimentation control measures will be used project-wide and shall be operated and maintained in accordance with necessary permit(s).

B. Water Circulation, Fluctuation, and Salinity Determinations

1. General Water Chemistry - The use of clean fill material would preclude any significant impacts on water chemistry during project construction. Some minor, short-term decreases in water clarity are expected from the proposed fill activities. No significant impacts on water color, odor, taste, dissolved oxygen levels, temperature or nutrient levels are anticipated.

2. Water Circulation, Fluctuation, and Salinity Determination

a. Current Patterns and Flow – The hydraulic structures on the Red River and Wild Rice River in combination with the diversion inlet structure will be operated in a manner that increases upstream water surface elevations (staging) during flood events. Water will be conveyed into the diversion channel for flood events where the peak flow forecasted for the Red River at the USGS gage in Fargo exceeds 9,600 cubic feet per second (cfs), which has a frequency of approximately 2 days per year on average (note: it does not happen every year for 2 days). Otherwise, these structures resemble bridges (with fully open gates). Above a flow of 9,600 cfs, the control structure gates will be partially closed as necessary to limit the flow continuing in the Red River through Fargo and Moorhead, to direct water to upstream staging areas and to divert flow into the diversion channel. There would be no significant change to current patterns and circulation for flows less than 9,600 cfs. The Sheyenne River and Maple River hydraulic structures will not increase upstream water surface elevations on the tributaries and will allow a minimum of the 50-percent chance event flow to pass through into the protected area. The pass through flow into the protected area will increase for larger events, but will always be less than the 10-percent chance event tributary flow. All excess flows will be directed into the diversion channel. Flow would be cut-off at the hydraulic structures on the Lower Rush and Rush Rivers and would be directed into the diversion. In general, local drainageways that are on the unprotected side and are interrupted by the diversion channel will be directed into the diversion channel, by way of new drop structures, for conveyance to the Red River. Furthermore, local drainageways that are interrupted by levees in the main line of flood protection at the south end of the project will be directed to one of the main rivers.

b. Velocity - The proposed diversion would result in some changes on the flow velocities upstream and downstream of the control structures on the Red River and Wild Rice River. These changes would occur when the gates at the control structures are partially closed (only when the peak flow forecasted for the Red River at the USGS gage in Fargo exceeds 9,600 cubic feet per second (cfs)) to limit the discharge passing into the protected area, and when upstream staging is induced to make use of available flood storage in the floodplain in order to eliminate impacts on flood levels downstream of the diversion works. As a result, flow velocities upstream of the control structure will be reduced in comparison to existing conditions, but both the with-project as well as the existing conditions velocities are relatively low across the very wide active floodplain. With-project flow velocities downstream of the Red River and Wild Rice River control structures will also be reduced in comparison to existing conditions, but this happens because the with-project discharge passing into the protected area will be smaller than the existing conditions to accomplish the project goal of providing flood damage reduction. In the case of the Sheyenne River and Maple River, the aqueduct crossing of the diversion channel has been designed to match the 50-percent chance event flow velocity under existing conditions. For the four design floods (10-percent, 2-percent, 1-percent, and 0.2 percent chance events) analyzed with the HEC-RAS unsteady flow model in the feasibility study, the difference between with-project and existing conditions is less than 1 foot per second (fps), and this is in great part due to the fact that the with-project discharge passing into the protected area is smaller than the existing conditions discharge. For more details, see Exhibit D and Exhibit G of Appendix F of Attachment 5.

c. Sedimentation Patterns- The preliminary assessment of potential project impacts on the sediment transport and geomorphologic characteristics of the affected rivers is presented in the SDEIS and Exhibit I of Appendix F of Attachment 5. There are four main conclusions and recommendations of this assessment (please reference the SDEIS and Exhibit I for full support).

1. The dominant form of sediment transport is in suspension, and the suspended sediments are primarily clays and silts that interact very little with the river bed, hence changes on flow velocity patterns should not have a significant effect on channel morphology (shape and longitudinal slope). When this is combined with the general assessment that the Red River is a very meandering but also a very morphodynamically stable riverine system (channel migration rates are relatively low), it is reasonable to conclude that the proposed configuration and operation of the diversion project is adequate and fits well the general setting of the project area.

2. The existing Horace to West Fargo diversion has been in place for nearly 20 years, and the impacts on the sediment transport and geomorphology of the Sheyenne River have not been significant. This existing diversion serves as a proxy of potential impacts of the proposed diversion.

3. Working with the sediment transport measurements by the USGS during the spring flood of 2010 and making conservative assumptions about sedimentation in the upstream staging area allows estimation of this sedimentation at less than 1 inch over the pass of a large flood hydrograph. Some of the conservative assumptions referred to above include, that all sediment mobilized over the pass of the flood hydrograph will settle upstream of the control structures, and that the relationship between discharge and sediment transport rates is non linear –with a exponent greater than one (even though the system is mobilizing primarily silts and clays as wash load). Sedimentation of less than 1 inch over the pass of the hydrograph is well within the range of sedimentation under existing conditions, as a result of sediment exchange between the channel and the floodplain, hence the project potential impact is not significant.

4. The alteration of river length at the location of the hydraulic structures is not large enough that it could result in sediment transport or geomorphologic impacts over the whole riverine system. However, the final design will provide a more detailed evaluation to ensure that project induced erosion or sedimentation is minimized. The assessment presented at this feasibility level will be validated through a pre-construction and post-construction monitoring plan created in cooperation with interested parties and agencies, and also through additional measurements during the most recent spring flood of 2011 and a parallel evaluation currently underway.

3. Actions Taken to Minimize Impact - Standard construction procedures in compliance with Federal and State requirements would be used. Design features for the hydraulic structures have been modified to minimize impacts, for example the control gates on the Red River structure have been widened to 50 feet from 40 feet.

C. Suspended Particulate/Turbidity Determination

1. Suspended Particulates and Turbidity - Turbidity and the concentration of suspended solids would be expected to increase temporarily during construction of project features. However, increases would be relatively minor and restricted to a relatively localized area. No long-term adverse impacts on water quality are expected.

2. Effects on Chemical and Physical Properties of the Water Column - Some minor short-term impacts on light penetration and aquatic organisms would occur during riprap placement. However, these effects would be rapidly dissipated upon project completion. No effects are expected on toxic metal concentrations, pathogens, or the aesthetics of the water column.

3. Actions Taken to Minimize Impacts – Impacts would be minimized by requiring that best management practices to limit the extent of turbidity plumes, such as silt curtains, would be followed during construction.

D. Contaminant Determinations - The use of clean, quarry-run rock riprap for construction would not introduce contaminants into the aquatic system. Neither the materials used nor the placement method would cause relocation or increases of contaminants in the aquatic system.

E. Aquatic Ecosystem and Organism Determinations

1. Effects on Plankton - During construction, increases in turbidity and suspended solids near the proposed fill activities might have a short-term localized effect on phytoplankton productivity. The plankton populations should recover quickly once the fill and other construction activities have ceased. In the long-term, overall aquatic habitat quality would improve, with resulting positive effects on plankton.

2. Effects on Benthos - Placement of rock during construction would cover and smother benthic communities located within the footprint of these structures. In-water excavation activities also would result in mortality of macroinvertebrates within these areas. However, rapid colonization of newly placed rock substrates would be anticipated with resulting minimal long-term effects. Benthic invertebrates also may re-colonize newly excavated channels leading in to and out of project structures.

3. Effects on Fish - Increases in turbidity and suspended solids during construction, as well as general noise and disturbance, would temporarily displace fish occupying the construction areas. Fish are more mobile than benthic invertebrates and

would likely avoid construction areas during construction. Upon completion, fish migration would be partially impeded during larger events. Fish migrations would be completed impeded only during the peak flow of the largest flood events. Impacts to migration would be minimized and mitigated by adding fish passage around the hydraulic structures. Under the LPP, fish passage also would be constructed at Drayton Dam as additional mitigation for impacts that are greater than those under the FCP and ND35K. During the largest flood events (e.g., flood events greater than approximately a 20-50 year flood event) fish passage would be completely blocked. However events of this magnitude occur very infrequently and fish passage channels could be active before and following the peak of such floods. For a more detailed discussion on effects on fish see section 5.2.1.7 of the Feasibility/EIS document.

4. Effects on Aquatic Food Web - The proposed fill activities are not expected to affect the total productivity of the Red River although there would be a temporary disruption to the aquatic biota present during project construction.

5. Effects on Special Aquatic Sites - There would be 1,161 acres of wetlands impacted by the diversion channel and features associated with construction of the LPP. These impacts would be either by the filling of wetlands or the excavation of wetlands.

6. Threatened and Endangered Species - No known Federally-listed threatened or endangered species would be affected by the project. The project has been coordinated with the U.S. Fish and Wildlife Service and it concurs with this determination.

7. Other Wildlife - The proposed fill activities would result in the loss of aquatic and terrestrial habitat, as outlined in Section 5.2.1.7 of the Feasibility EIS/Document. However, significant habitat losses as a result of the proposed fill activities will be mitigated for as outlined in Attachment 6 of the Feasibility/EIS document (Mitigation and Adaptive Management). The general diversity and productivity of the affected areas would be maintained.

8. Actions Taken to Minimize Impacts – The diversion alignment was selected to avoid, to the extent practicable, existing wetlands. Wetlands will be established along the bottom of the diversion channel during construction. During the design phase there will be features added to create wetlands; features used to facilitate the creation of wetlands will include meandering the low flow channel, constructing rock riffles in locations to create ponding, and other features developed during the design phase. A mitigation plan (Attachment 6 of the Feasibility/EIS document) is also in place to mitigate for impacts caused by the construction of the hydraulic structures. Fish passages would be constructed around the hydraulic structures. A floodplain forest mitigation plan is also included in Attachment 6.

F. Proposed Disposal Site Determinations

Section 404(b)(1) Evaluation

1. Mixing Zone Determination - The proposed fill activities would have minimal mixing zones. The fill material used for the project would be large and relatively clean so that very little exposed material could be suspended in the water column.

2. Determination of Compliance with Applicable Water Quality Standards The fill materials used for this project would be obtained from approved quarries in the project area or excavated on-site. The area does not have a history of contamination, which should insure that State water quality standards would not be violated because of project-related activities. Water quality certification from Minnesota and North Dakota would be obtained prior to project construction.

3. Potential Effects on Human Use Characteristics - The proposed project would provide community flood protection without adversely affecting the river. The land acquired for the project would provide locations for the installation of recreational features. Water related recreational use of the project area would not be adversely affected by the project at normal flows. During high flows when the control structures are under operation, recreational use (boaters, jet skis, canoes, kayaks, etc.) will not be allowed to pass through the structure on the Red River or the Wild Rice Rivers due to safety concerns.

G. Determination of Cumulative Effects on the Aquatic Ecosystem - See section 5.4 Cumulative Effects in the Feasibility/EIS document.

H. Determination of Secondary Effects on the Aquatic Ecosystem – There could be some indirect impacts to wetlands adjacent to the 36 mile diversion channel. This is unlikely because the soil types are not very permeable, which limits the potential for percolation, and any wetlands within 600 feet of the excavated channel will have already been accounted for as filled by the side cast of material from the diversion excavation. The Lower Rush River and Rush River will have 5.7 miles of abandoned channel which will be maintained as wetland habitat. Disturbed aquatic habitat would be expected to quickly recover after construction.

III. FINDING OF COMPLIANCE WITH RESTRICTIONS ON DISCHARGE

The proposed fill activities would comply with Section 404(b)(1) guidelines of the Clean Water Act, as amended. No significant adaptations of the guidelines were made for this evaluation. Other alternatives considered to reduce the flood risk to the Fargo Moorhead Metropolitan area included no action - continue emergency measures; nonstructural measures; flood barriers; increased conveyance; flood storage; and other diversion channel alignments. Other alternatives were not selected because they were prohibitively more costly, were significantly less effective in reducing flood risk, had extensive downstream impacts that would have been logistically very difficult to mitigate for, or did not meet the overall project purpose of reducing flood risk from both the Red River and the five North Dakota tributaries. A discussion of the effects associated with the operation of the project and project features is presented in the Feasibility/EIS document. The placement of dredged and fill material for the proposed project is required to achieve the project purpose. The proposed project is the least environmentally damaging practicable alternative that would achieve the overall project purpose of reducing flood risk from both the Red River and the five North Dakota tributaries. The NED plan and FCP described above would reduce flood risk from the Red River and the Wild Rice River, but not the other four North Dakota tributaries, and the ND35K plan is not practicable due to the logistics of mitigating its extensive downstream impacts.

The proposed fill activities would comply with all State water quality standards, Section 307 of the Clean Water Act, and the Endangered Species Act of 1973, as amended. The proposed fill activities would not have significant adverse effects on human health and welfare, including municipal and private water supplies, recreation and commercial fishing, plankton, fish, shellfish, wildlife, and special aquatic sites. The life stages of aquatic life and other wildlife would not be adversely affected. Significant adverse effects on aquatic ecosystem diversity, productivity, and stability and on recreational, aesthetic, and economic values would not occur.

To minimize the potential for adverse impacts, the fill would be placed during periods of normal to low water levels. Since the proposed action would result in few adverse effects, no additional measures to minimize impacts would be required.

A public hearing was held for this Section 404(b)(1) evaluation on June 1, 2011 in Fargo, ND. Statements received at that hearing and during the following comment period were considered in this evaluation.

On the basis of this evaluation, I have determined that the proposed action complies with the requirements of the 404(b)(1) guidelines for the discharge of fill material.

15 July 2011
Date

Michael J. Price
Colonel, Corps of Engineers
District Engineer

Attachment 2

Fargo-Moorhead Metro

Final Feasibility Report and Environmental Impact Statement

July 2011

U.S. Fish and Wildlife Coordination Act Report

Fish and Wildlife Coordination Act

Final Report

Fargo-Moorhead Metropolitan Area Flood Risk Management Project

July 14, 2011

Prepared by:

Twin Cities Field Office
Division of Ecological Services
Bloomington, Minnesota

U.S. Fish and Wildlife Service
Region 3

Fish and Wildlife Coordination Act Report

Colonel Michael J. Price
District Engineer,
U.S. Army Corps of Engineers
St. Paul District
180 Fifth Street East, Suite 700
St. Paul, Minnesota 55101-1678
Attention: Aaron M. Snyder

Subject: Fargo-Moorhead Metropolitan Area Flood Risk Management Project
Cass and Richland Counties, North Dakota
Clay and Wilkins Counties, Minnesota
Final Fish and Wildlife Coordination Act Report
FWS TAILS #32410-2009-FA-0143

Dear Colonel Price:

This is the Service's official transmittal of the Final Fish and Wildlife Coordination Act Report pertaining to the Fargo-Moorhead Metropolitan Area Flood Risk Management Project. Submittal of this Report is in accordance with the February 2011 Scope of Work between the Service and Corps.

Please contact me at (612) 725-3548, ext. 2201, or Rich Davis, Fish and Wildlife Biologist, at (612) 725-3548, ext. 2214, if you questions regarding this report or if we can be of further assistance.

Sincerely,

Tony Sullins
Field Supervisor

INTRODUCTION

The Red River of the North and its associated watershed has experienced several large-scale flood events in the past decade. Significant financial damage resulting from these events has led to several coordinated local, state, and federal agency attempts to address flood-related impacts within the Red River Basin. In September 2008, officials from the City of Fargo, North Dakota and City of Moorhead, Minnesota along with the U.S Army Corps of Engineers (Corps) entered into a Feasibility Cost Share Agreement. The Corps then issued a Notice of Intent to complete an Environmental Impact Statement (EIS) in the May 5, 2009 Federal Register. Due to unanticipated potential downstream impacts of the proposed project alternative operational measures have been developed, and a Supplemental Draft EIS is being completed by the Corps. Accordingly, the Fargo – Moorhead Metropolitan Area Flood Risk Management Feasibility Study focused on alternatives that would alter and/or protect the Cities of Fargo and Moorhead against elevated flood levels from the Red River.

In 2010, the Corps completed Phase 3 of project analysis and determined that the North Dakota 35,000 cfs (ND 35K) alternative would require modification due to unexpected downstream impacts, which would result from Red River stage increases caused by the diversion channel operation. To reduce downstream impacts the Corps modified the LPP, which includes a 20,000 cfs diversion channel, along the original ND 35K alignment, construction of a temporary storage area, and staging flood waters upstream of the proposed control structure. The storage area would be constructed within the protected area adjacent to the southern end of the diversion channel. Upstream staging of flood waters would be accomplished through the operation of the control structure located within the main stems of the Red River and Wild Rice River. Control structures will be operational when forecasted peak flows are anticipated to exceed 9,600 cfs at the Fargo USGS gage station.

Phase 3 project analysis identified the Minnesota 35,000 cfs alternative as the Federally Comparable Plan (FCP), which will be used to compare to the LPP for cost-share, annual benefit, and residual damage purposes. An FCP is necessary as the LPP provides fewer average annual benefits then the National Economic Development (NED) plan, which was determined to be the Minnesota 40,000 cfs alternative.

The ND 35K alternative was carried forward in the SDEIS, so this report addresses the ND 35K alternative and possible impacts resulting from this alternative.

Under the FCP, the majority of the impacted lands along a diversion channel alignment in Minnesota would consist of agricultural lands. The LPP and ND 35K will impact five tributaries to the Red River; the Wild Rice River (North Dakota), Sheyenne River, Maple River, Lower Rush River, and the Rush River. Common resource concerns between the Minnesota and North Dakota Alternatives include the Red River channel impacts, construction of a control structure within the Red River, loss of fish passage within the main stem of the Red River, sedimentation issues in the Red River, loss of riparian habitat, wetland impacts, and the fate of fish entering the diversion channel during flood events.

The LPP will stage floodwaters upstream (south) of the proposed control structure on lands adjacent to the Red River and the Wild Rice River. Staging will be controlled by operation of the control structures, and will only occur during events where the forecasted peak flows are anticipated to exceed 9,600 cfs at the Fargo USGS gage. Staging will cause the control structure gates to be in operation longer while water is held back, which will result in reduced fish passage through the control structures. Fish passageway structures are proposed at the Red River and Wild Rice River control structures, which will allow some fish passage when the control structures in operation. The majority of the lands to be inundated by upstream staging are primarily agricultural lands, so impacts to wildlife habitat areas should be minimal. Negative hydrologic impacts to wetlands within the staging area are not anticipated to occur, due to the infrequency of storm events that will require staging and the time of staging, prior to the active growing season.

The U.S. Fish and Wildlife Service (Service) is authorized under the Fish and Wildlife Coordination Act (16 U.S.C. 661 et seq.) to provide reports on federally funded water development projects. The Fish and Wildlife Coordination Act (FWCA) states that fish and wildlife resources shall receive equal consideration with other project purposes in federal water resource development program activities.

In accordance with the October 2009 Scope of Work (SOW) for the proposed project review and Draft EIS, the Service issued a project review letter on February 1, 2010 and a Draft FWCA Report on May 27, 2010 to the Corps. A Revised SOW was generated and finalized on February 14, 2011 to involve the Service in the review and assistance with the revised project and the associated Supplemental Draft and Final EIS documents. This report constitutes the report of the Secretary of the Interior as required by Section 2(b) of the FWCA and, when finalized, will fulfill the Service's commitment as outlined in the Revised SOW.

The Minnesota Department of Natural Resources (MNDNR) and North Dakota Game and Fish Department provided valuable information regarding resources in the Red River and the Red River Valley and the project area for incorporation into this report. The MNDNR and the North Dakota Game and Fish Department participated in several joint agency discussions on project alternatives.

STUDY AREA

The rich soils and extremely flat terrain of ancient glacial Lake Agassiz located in and around Fargo and Moorhead supports a largely rural and agricultural community with the majority of development occurring in the metropolitan area. Human activities have induced significant environmental changes within the watershed, engineered by numerous drainage ditches, stream channelization, and subsurface tile drainage. The average annual precipitation for Fargo, North Dakota is 21.29 inches.

The proposed project will influence the following major watersheds in North Dakota; Western Wild Rice River, Lower Sheyenne River, and the Maple River. The Red River major watershed is in North Dakota and Minnesota, and will be influenced by the proposed project. The Buffalo River major watershed in Minnesota could also be influenced by the proposed project.

Large wetland complexes are rare within the proposed project area, and the affected portions of the surrounding watersheds. Smaller wetlands are scattered throughout the interior of the watershed and have been heavily impacted by human activities.

The main collection point for surface runoff and drainage in the project area is the Red River, which is also influenced by the in flows of the Wild Rice (ND), Sheyenne (ND), Maple (ND), Lower Rush (ND), Rush (ND), and the Buffalo (MN) Rivers (Figure 1). The Red River originates at Lake Traverse to the south, and flows north where it enters Lake Winnipeg. The Red River and the associated Valley are generally flat with a south to north, channel gradient slope that averages a one-half foot fall per mile.

Stream flow measurements taken at a USGS gauge station in the Red River at Fargo, North Dakota show mean monthly flows in winter months (2009-2010) of 1,000 cubic feet per second (cfs). However, stream flow data collected in mid March of 2010 showed flows exceeding 20,000 cfs in the Fargo, ND area. Portions of the Red River and its tributaries, affected by this project, have been channelized or impacted by flood reduction and drainage improvement projects in the past which include bank armoring, floodplain levees, ditching, and tiling.

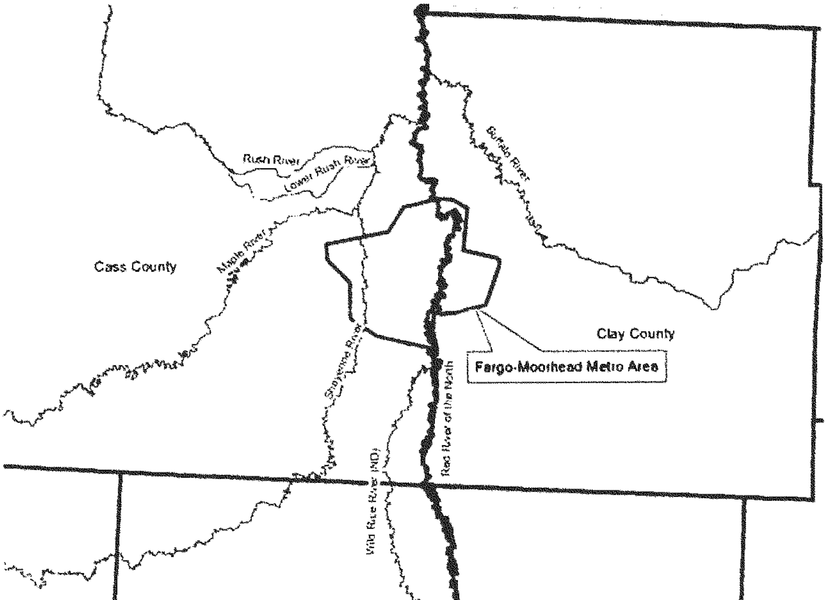


Figure 1. Rivers in close proximity to or within the Fargo-Moorhead Metropolitan Area.

FISH AND WILDLIFE RESOURCES

This section describes existing conditions for fish, wildlife, and habitat resources within the project area that may be either directly or indirectly impacted by the alternatives considered. This area includes the various diversion channel alternatives around Fargo/Moorhead (Figure 2) as well as the riparian corridors along the Red, Wild Rice (North Dakota), Sheyenne, Maple, Lower Rush, and the Rush River.

Riparian vegetation along the Red River and tributaries is heavily influenced by the extensive amount of agriculture in the area and the frequent flood events. Tree canopy and understory species typical of disturbed habitats are the primary dominates in the vegetated riparian zone. The riparian corridor provided by the Red River is the most protected method of travel for wildlife species in the project area. Wildlife capable of adapting to a variety of changing habitats, such as raccoon, skunk, and deer, are common closer to the metropolitan area. A list of wildlife species found through the project site is in Appendix 1.

The landscape surrounding Fargo/Moorhead, outside the Red River riparian zone, provides only small pockets of wildlife habitat in the form of woods, wetlands, and grasslands. There are many agricultural fields that harbor important short-term open water habitat for migratory birds in the spring. Although the extent of these ephemeral, open water areas has not been mapped, aerial photography suggests they are prevalent throughout the area. These areas provide critical feeding and resting areas for migratory birds, especially if precipitation or snowmelt has inundated other shallow water habitats in their migratory path.

The Red, Wild Rice (North Dakota), Sheyenne, Maple, Lower Rush, and Rush Rivers, support both game and non-game fish (Appendix 1). Diversity, abundance, and distribution of fish are largely dependent upon existing barriers, water quality issues and winterkill due to low flow events. The Fargo/Moorhead area is known for its sport fishing opportunities, including channel catfish, walleyes, and northern pike. The sport fishery has benefited greatly from MNDNR efforts in removal of low head dams and stocking efforts. Lake sturgeon reintroduction efforts within the Red River and its tributaries have been successful in re-establishing this species within the river system including the Fargo-Moorhead metro area.

Several mussel species have also been documented within the Red River and tributaries. Some survey work was completed in 2008, in the Fargo/Moorhead area, by the MNDNR, but minimal data currently exists for mussel species present within the Red, Wild Rice (ND), Sheyenne, Maple, Lower Rush, and Rush Rivers.

Biotic surveys within the Red, Wild Rice (ND), Sheyenne, Maple, Lower Rush, and Rush Rivers are scheduled to occur in the Spring/Summer of 2011 and 2012. Results of these surveys, as made available to the Service, will be incorporated into the Final FWCA Report for the Fargo/Moorhead Project.

Wetlands

The majority of the wetlands within the proposed project area are palustrine emergent, palustrine forested, and riverine wetlands. The majority of the wetlands within the project area are located along the river corridors. Many of the small isolated wetlands outside the riparian zone are influenced by agriculture activities (drainage, tillage, grazing, etc.). Temporarily flooded basins, including actively farmed basins, have the potential to provide excellent "stop-over" habitat for spring migrating birds.

Federal Candidate, Threatened, and Endangered Species

Five listed or candidate species under the Endangered Species Act of 1973 (ESA), as amended, occur within Clay and Wilkins Counties, Minnesota and Cass and Richland Counties, North Dakota.

Clay County, Minnesota
- Dakota skipper (Candidate)
- Sprague's pipit (Candidate)
- western prairie fringed orchid (threatened)

Wilkins County, Minnesota – No Listed Species

Cass County, North Dakota –
- whooping crane (Endangered)
- gray wolf (Endangered)

Richland County, North Dakota –
- Dakota skipper (Candidate)
- western prairie fringed orchid (threatened)
- whooping crane (Endangered)
- gray wolf (Endangered)

According to data available at the time of drafting this report there is record of western prairie fringed orchid in Richland County, ND, which could potentially be affected by the upstream staging of flood water. Records indicate the last observation of orchids in this location occurred in 1984. Additional field surveys in coordination with the Service will be necessary to determine the presence of western prairie fringed orchid at previously identified locations.

Current data does not indicate records of whooping crane, gray wolf, or Dakota skipper within the proposed project area. If at any point during project planning, construction, or operation should additional information on listed species become available, or should a new species be listed, the Corps will reinitiate consultation with the Twin Cities Field Office of the Service.

Bald Eagle Nests

Bald eagles and their nests are protected from take and disturbance, respectively, per the Bald and Golden Eagle Protection Act. The Service verified the location of two bald eagle nests within the proposed project area. One nest is located on the northwest edge of the City of Fargo along the Sheyenne River in close proximity to a housing development. It was also verified with local private residents in the area that the nest was active and successful in 2009. The other nest is located north of the Cities of Fargo and Moorhead, close to the confluence of the Sheyenne River and the Red River.

A third bald eagle nest has been identified during desktop and map analysis of the proposed flood staging area upstream of the proposed Red River control structure. The identified nest is approximately 5.5 miles south of proposed control structure and diversion channel construction activities. Under existing conditions, 5, 10, 50, 100, and 500 year storm events place flood waters around the third nest tree. Proposed project operation will result in longer durations of staging flood waters around the nest tree. Increased inundation is not anticipated to have a direct negative impact on adult or juvenile bald eagles utilizing the nest, but increased inundation could potentially affect the structural integrity of the nest tree. The Service and Corps staff attempted to verify activity of this nest from public roads on May 25, 2011. The third eagle nest location was not verified in the field, which could have been due to reduced visibility caused by leaf out or the nest may have fallen since it was recorded.

During the planning, construction, and operational phases of the Fargo-Moorhead project the Service's National Bald Eagle Management Guidelines (May 2007), http://www.fws.gov/midwest/MidwestBird/EaglePermits/index.html, should be utilized to reduce impacts to any and all bald eagles nesting within the proposed project area. Because of the long timeline associated with this project (eight plus years) the Service recommends that raptor nest surveys be completed in all wooded areas potentially affected by this project. The raptor nest surveys should be completed at a minimum in the spring of the year proceeding construction within or near any affected wooded areas. If negative structural impacts to the third eagle nest, are anticipated due to the increased duration of inundation, a Non-intentional Nest Take Permit (50 CFR 22.26) may be necessary. These permits are valid for five year periods, the local project sponsors should consider applying for these permits in years when large flood events are anticipated and the resulting flood water staging could affect the eagle nest tree. The permitting process can take two to three months to complete depending on complexity, and all permits require minimization, mitigation, and monitoring measures.

Migratory Birds

Due to the varied habitat and cover types throughout the project site, there is the potential to impact wetlands, grasslands, and woodlands during the construction or excavation phases necessary to complete this type of project. The aforementioned habitat types can provide nesting habitat for a variety of migratory bird species. Upon final selection of a path for the diversion channel and levee alignments, mapping of significant migratory bird nesting areas should be coordinated with the Service.

Development of a construction timeline to minimize impacts to these areas during prime nesting times should be considered. The Service recommends that proposed construction and excavation within potential bird nesting habitat be completed outside of the primary nesting period (April 1st to August 31st) when possible and feasible. Attempts to minimize impacts to potential migratory bird nesting habitats should be made at all times during construction and excavation.

Executive Order 13186 (EO 13186), specifically addresses the responsibilities of federal agencies to protect migratory birds. EO 13186 includes a directive to federal agencies to restore and enhance the habitat of migratory birds as practicable, which provides a basis and a rationale for mitigating for the loss of migratory bird habitat that result from developing the proposed project.

ALTERNATIVES

During the original screening process of the proposed project, 11 alternatives were evaluated to determine which would be most the implementable, and which alternatives would move forward for further analysis. The Corps Alternative Screening Document, December 2009, provides explanation of the screening process, and provided the recommendation that the No Action and Diversion Channel alternatives should be carried forward for further evaluation as stand-alone alternatives.

No Action

This alternative represents future conditions without the project. Major flood events, such as 100-year events and higher, would continue to occur on a periodic basis. Land use in and surrounding the Cities of Fargo and Moorhead would remain the same. The alternative also anticipated that both Cities would continue to expand as population growth and economy allowed. The Cities would continue to rely on emergency flood protection measures; existing levee protection, temporary levees and floodwalls, and sand bagging activities that are completed as needed in response to flooding.

Flood Barriers

This alternative includes the use of permanent flood barrier measures such as levees, floodwalls, invisible floodwalls, gate closures, and pump stations. For analysis purposes the flood barriers alternative would have resulted in levees on both the Fargo and Moorhead sides of the Red River. Two levee top profiles were considered by the Corps, which could reliably contain the 2% chance and the 1% chance of flooding. This alternative was not pursued further as a stand-alone alternative by the Corps for the purposes of this project.

Diversion Channel

A diversion channel would direct flood waters from the Red River into a constructed channel around the Cities of Fargo and Moorhead, and eventually the diverted waters would enter back into the Red River downstream of Fargo/Moorhead. During early planning stages of the project the Corps developed multiple diversion channel alignments on both the Minnesota and North Dakota side of the Red River.

The local sponsors of the Fargo/Moorhead project requested that the Corps move forward with the North Dakota 35,000 cfs making it the Locally Preferred Plan (LPP). Both the MN 35K and the ND 35K would provide diversion of flood waters, around the metropolitan area, starting at 9,600 cfs flow event. However, the local sponsors felt that the ND 35K Alternative provided more local flood reduction benefits then the Minnesota alternatives. The LPP and ND 35K will assist in reducing potential flooding impacts caused by the Wild Rice and Sheyenne Rivers. Due to downstream impacts of Red River stage increases, the ND 35K alternative was modified and the current LPP was developed. The LPP consists of a 20,000 cfs diversion channel constructed along the same alignment as the ND 35k, and the construction of control structures on the Red River and Wild Rice River will be operated when the forecasted peak flow is anticipated to exceed 9,600 cfs at the Fargo USGS gage. The LPP involves upstream staging of Red River and Wild Rice River flood waters, and the storage of waters directed through the diversion channel into holding basins proposed to be constructed adjacent to the south end of the diversion channel. The MN 35K alternative has been identified as the Federally Comparable Plan (FCP), which can be compared to the LPP for federal cost share purposes.

Under the FCP, the majority of the impacted lands along a diversion channel alignment in Minnesota would consist of agricultural lands. The LPP and ND 35Kwill impact five tributaries to the Red River; the Wild Rice River (North Dakota), Sheyenne River, Maple River, Lower Rush River, and the Rush River. Common resource concerns between the Minnesota and North Dakota Alternatives include the Red River channel impacts, construction of a control structure within the Red River, loss of fish passage within the main stem of the Red River, sedimentation issues in the Red River, loss of riparian habitat, wetland impacts, and the fate of fish entering the diversion channel during flood events.

Non-structural Measures

This alternative encompasses various flood-proofing measures such as relocating businesses and residential structures to an area outside the floodplain, elevation of structures, land acquisition and buyouts, basement removals, dry and wet flood proofing, and additional flood preparedness plans and warnings. Due to highly negative social impacts and the extremely high costs associated with this alternative, non-structural measures were not further considered as a stand-alone alternative by the Corps for the purposes of this project. The Corps did make the recommendation that the non-structural alternative should be considered for possible inclusion as a feature of the overall plan where it could be incrementally justified.

Flood Storage

The storage alternative involves preservation of natural floodplain, restoration of wetlands, and the construction of dams and other water retention facilities throughout the watershed. Utilization of agricultural fields for flood water retention would need to be a major component of this alternative. Through modeling the Corps determined that the storage alternative would have low effectiveness in larger flood events, but may be helpful in small flood events. Due to the low level of effectiveness during large flood events and the high costs associated with this alternative, flood storage was not further considered as a stand-alone alternative by the Corps for the purposes of this project. The Corps did make the recommendation that the flood storage alternative should be considered for possible inclusion as a feature of the overall plan where it could be incrementally justified, and it should be considered by the local communities within the basin.

Tunneling

This alternative would entail the construction of a series of tunnels under the Cities of Fargo and Moorhead to convey floodwaters, and reduce the water levels in the Red River. This alternative would provide similar benefits to the diversion channel alternatives, but with a much greater cost. There would also be significant negative impacts to aquatic habitats and fish passage associated with the tunneling alternative. Due to the high costs and uncertainties of long term maintenance associated with this alternative, tunneling was not further considered as a stand-alone alternative by the Corps for the purposes of this project.

Bridge Replacement or Modification

Bridge replacement or modification was considered because in some cases this can increase water conveyance and reduce flood stages within the river. However, in the case of Fargo/Moorhead and the Red River, the Corps determined that complete removal of the bridges had only a minor affect on flood levels. Due to the low level of effectiveness and the high costs associated with this alternative, bridge replacement or modification was not further considered as a stand-alone alternative by the Corps for the purposes of this project. The Corps did make the recommendation that the bridge replacement or modification alternative should be considered for possible inclusion as a feature of the overall plan where it could be incrementally justified.

Interstate 29 Viaduct

This alternative would involve reconstruction of the existing Interstate 29 corridor to function as an open viaduct during flood events. During non-flood times the corridor would then function as an interstate highway. This alternative would have significant negative impacts for fish passage and sedimentation, and there would be minimal environmental benefit as the interstate corridor would function as a highway during non-flood periods. Due to the low level of cost effectiveness and unacceptable transportation impacts associated with this alternative, the Interstate 29 viaduct was not further considered as a stand-alone alternative by the Corps for the purposes of this project.

Dredging and Widening the River

An alternative to deepen and widen the Red River to accommodate great flow conveyance through the Fargo/Moorhead area was considered. This alternative would result in substantial environmental impacts including; increased sedimentation, loss of suitable fish and mussel habitats, riparian habitat loss, wildlife mortality during excavation activities, and a high likelihood of riverbank instability issues. There would also be social impacts as homes and property would need to be acquired to insure the Red River could be widened to accommodate the new river depths. This alternative would also violate a number of local and national policies. Due to associated policy violations and the high costs associated with long term maintenance of this alternative, dredging and widening of the Red River was not further considered as a stand-alone alternative by the Corps for the purposes of this project.

Wetland and Grassland Restoration

Wetland and grassland restoration areas could be established to provide flood storage and also reduce peak runoff. Costs of this alternative were anticipated to be high due to large land acquisition needs to implement restoration activities. The Corps staff determined that the benefits of wetland restoration would be localized, and the flood storage needs of the Fargo/Moorhead area would not be met. Due to the low level of effectiveness to offset flood damages, high costs, and the large land acquisitions associated with this alternative, wetland and grassland restoration was not further considered as a stand-alone alternative by the Corps for the purposes of this project. The Corps did make the recommendation that the wetland and grassland restoration alternative should be considered for possible inclusion as a feature of the overall plan where it could be incrementally justified.

Throughout the project and comment process the Service has recommended that the Corps consider the utilization of wetland restoration within the watershed of the project to increase flood water storage and attenuation.

Cut-off Channels

Cut-off channels would be excavated across meanders within the Red River channel in the Cities of Fargo and Moorhead. Straightening the channel would allow greater conveyance of water through the Cities, and potentially reduce peak flood stages. This alternative would impact riparian habitat, wetlands, and potentially fisheries resources that are adjacent to or utilize these meanders. According to Corps staff this alternative would not provide substantial flood risk reduction. There would also be the potential for this alternative to violate state and federal policies. Due to the low reduction of flood risk and the environmental impacts associated with this alternative, cut-off channels was not further considered as a stand-alone alternative by the Corps for the purposes of this project. The Corps recommended that the cut-off channels alternative be considered for possible inclusion as a feature of the overall plan where it could be incrementally justified.

Locally Preferred Plan (LPP)

This alternative is located west of the Cities of Fargo and Moorhead, with an inlet planned to be constructed south of the Fargo/Moorhead metropolitan area on the Red River approximately 4 miles south of the confluence of the Red River and the Wild Rice River (North Dakota), see Figure 2. The outlet of the diversion channel into the Red River is planned to be constructed north of the Fargo/Moorhead metropolitan area on the Red River approximately 3.5 miles north of the confluence of the Red River and the Sheyenne River.

The connecting channel bottom width between the Red River and the diversion channel inlet weir is 100 feet, and the diversion channel downstream of the inlet weir will have an average bottom width of 250 feet, and internal 1(vertical):7(horizontal) side slopes. The peak of the spoil piles adjacent to the diversion channel will not exceed 15 feet above existing grade. Spoil slopes will be 1:7 internally and 1:10 externally. Total width of the diversion channel construction including; bottom width, internal slopes, and external side slopes will be approximately 2,200 feet. With a total length of approximately 36 miles, the total affected footprint of the diversion channel is approximately 9,600 acres.

The inlet of the diversion channel located east of the Sheyenne River will consist of a passive weir structure with a concrete spillway. A large control structure is proposed to be placed in the Red River channel, downstream of the connection channel inlet. The concrete structure will have three gates, 50 ft wide x 50 ft high. A natural variable bed roughness through the control structure is proposed to provide variable flow velocities. During normal flows the control structure would be completely open, and during flow events exceeding the 3.5 year storm event (9,600 cfs) the gates would partially close and the structure would act as a barrier that would back water into the diversion channel. Two or more gated fish bypass channels are proposed on the east side of the Red River structure. Proposed bypass channels will function to the extent practicable up to a 50 year storm event, and upstream headwater variation will affect the placement, number, and function of the proposed fish bypass channels.

A second weir structure will be constructed within the connection channel on the east bank of the Wild Rice River (ND). This second weir structure will be over topped by diverted flows from the Red River once a 9,600 flow event is exceeded. A gated control structure will be constructed in the Wild Rice River (ND), with two tainter gates (30 feet wide and 30 feet high). A natural variable bed roughness through the control structure is proposed to provide variable flow velocities. The gates will generally be fully open, but during large flow events the gates will be lowered to restrict the flow into the Fargo-Moorhead Metro. Flows above the 3.5 year event would overtop the inlet weir, located east of the Sheyenne River, into the diversion channel. Two or more gated fish bypass channels are proposed to be constructed adjacent to the Wild Rice River control structure. Proposed bypass channels will function to the extent practicable up to a 50 year storm event, and upstream headwater variation will affect the placement, number, and function of the proposed fish bypass channels.

Diverted flood waters will flow west and north around the Fargo/Moorhead metropolitan area. The diversion channel will affect four additional tributaries; the Sheyenne River, the Maple River, the Lower Rush River, and the Rush River.

Concrete bypass structures (aqueducts) will be built to convey waters within the tributaries over the diversion channel. The structures will allow the Sheyenne and Maple Rivers to flow through under normal conditions. However, flows exceeding the 2 year storm event within the Sheyenne and Maple will overtop small weir structures and flow through constructed channels into the main diversion channel. The Lower Rush and Rush Rivers will be routed, via drop structures, directly into the diversion channel. Fishways consisting of 40 foot wide riffle-pool sequences will be constructed to extended from the Lower Rush and Rush Rivers down to the low flow channel within the diversion channel. The channels of the Lower Rush and Rush Rivers between the diversion channel and downstream to their confluences with the Sheyenne River will be abandoned, and allowed to function as temporary flooded open ditches and as wetland habitat during the drier periods of the growing season. During flood events up to the 2 year event the Maple River aqueduct will convey cut off flows from the Rush and Lower Rush Rivers into the protected area.

The diversion channel will outlet into the Red River 1.5 miles south of the Red River/Buffalo River confluence through a 250 foot wide concrete spill way.

A three mile tie back levee will need to be constructed to connect the Red River control structure to high ground. The tie back levee contains a small control structure (two 10 foot by 10 foot gated box culverts), which would be placed within Wolverton Creek. The Wolverton Creek structure will be closed during flood events. The levee will prevent flood waters from flowing over land to north and east into the Fargo/Moorhead metropolitan area. An additional 6.8 mile tie back levee will be need to be constructed along Cass County Road 17 to keep staged flood waters from flowing overland to the Sheyenne River.

A significant structural and operational component to the LPP to eliminate downstream impacts of the proposed project is to provide upstream staging of flood waters and provide floodwater storage. Staging of approximately 200,000 acre feet of water is necessary upstream of the diversion channel inlet. A 4,360 acre storage area (Storage Area 1) will be constructed on the north side of the connection channel between the Wild Rice and Sheyenne Rivers. Storage Area 1 will be connected to the connection channel, and water levels within the storage area will rise and recede in correspondence to connection channel water levels. Flood water staging will be controlled by operation of the control structures, and will only occur when the forecasted peak flows are anticipated to exceed 9,600 cfs at the Fargo USGS gage. Longer staging will cause the control structure gates to be in operation longer while water is held back, which will result in reduced fish passage through the structures. The majority of the lands to be inundated by upstream staging are primarily agricultural lands, so impacts to wildlife habitat areas should be minimal. Hydrologic effects to wetlands are not anticipated to occur due to the infrequency of events that will require additional staging, and the majority of staging events will occur during spring snowmelt and early spring precipitation events which tend to occur prior to the beginning of the active growing season.

During operation the LPP alternative is anticipated to produce the following downstream impacts:

- 10 year event maximum impact location downstream stage increase 1.4 inches
- 50 year event maximum impact location downstream stage increase 4.6 inches
- 100 year event maximum impact location downstream stage increase 3.5 inches
- 500 year event maximum impact location downstream stage increase 3.2 inches

During operation the LPP alternative is anticipated to produce the following upstream impacts:

- 10 year event Hickson gage location upstream stage increase 79.0 inches
- 50 year event Hickson gage location upstream stage increase 55.0 inches
- 100 year event Hickson gage location upstream stage increase 64.6 inches
- 500 year event Hickson gage location upstream stage increase 34.2 inches

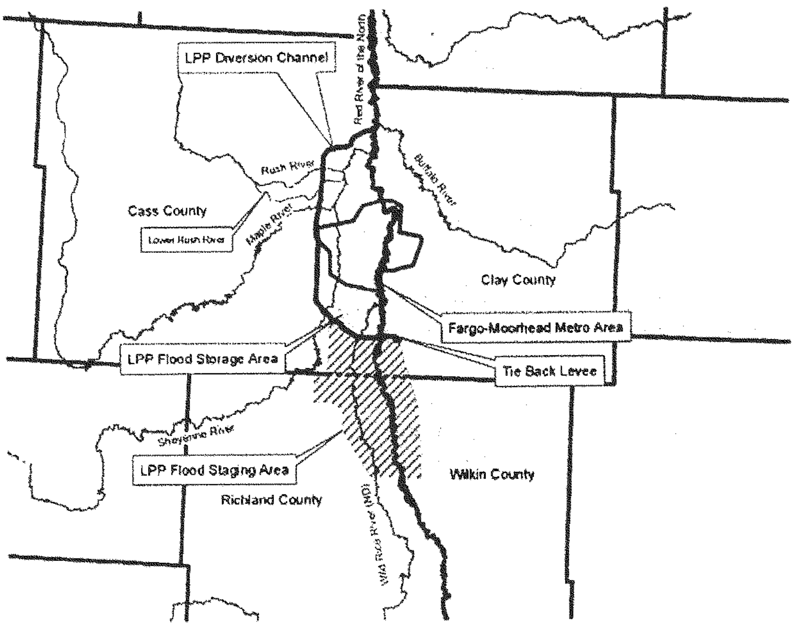


Figure 2. Proposed LPP Diversion Channel Alternative

MN 35K Diversion Channel (FCP)

This alternative is located east of the Cities of Fargo and Moorhead, with an inlet planned to be constructed south of the Fargo/Moorhead metropolitan area on the Red River north of the confluence of the Red River and the Wild Rice River (North Dakota), see Figure 3. The outlet of the diversion channel into the Red River is planned to be constructed north of the Fargo/Moorhead metropolitan area on the Red River, north of the confluence of the Red River and the Sheyenne River.

The diversion channel will have an average bottom width of 400 feet, and internal 1(vertical):7(horizontal) side slopes. The internal side slopes will be increased to 1:5 at highway and railroad intersections. The peak of the spoil piles adjacent to the diversion channel will not exceed 15 feet above existing grade, and external side slopes of the diversion channel will range from 1:7 to 1:10. Total width of the diversion channel construction including; bottom width, internal slopes, and external side slopes will be approximately 2,150 feet. With a total length of approximately 25 miles, the total affected footprint of the diversion channel is approximately 6,415 acres.

The inlet of the diversion channel on the east bank of the Red River will consist of a metal sheet pile and rock weir structure. Water from the Red River will begin to flow over the weir structure after a 9,600 cfs event is exceeded. Once the water has overtopped the weir structure the diversion channel will go east and north around the Fargo/Moorhead metropolitan area. The diversion channel will primarily bisect land currently used for agricultural production. The diversion channel will outlet into the Red River over a rip rap structure.

The diversion channel will function as a temporary flooded open ditch during the conveyance of flood waters, and as mix of channel habitat and wetland habitat during low flow periods.

A large control structure is proposed to be placed in the Red River channel, approximately 1,600 feet downstream of the diversion channel inlet. The concrete structure will have three gates, each 40 feet wide by 40 feet tall. During normal flows the control structure would be completely open, and during flow events exceeding 9,600 cfs the gates would partially close and the structure would act as a barrier that would back water into the diversion channel. A concrete fish ramp is proposed for construction to allow fish passage up to the 50 year storm event.

A 9.9 mile tie back levee will need to be constructed to connect the Red River control structure to high ground. The levee will prevent flood waters from flowing over land to north and west into the Fargo/Moorhead metropolitan area.

In addition to the main diversion channel this alternative would include to smaller channels upstream of the Red River structure. A three mile long supplementary channel will run south parallel to the Red River to allow for additional capacity, see Figure 3. A second supplementary channel, less then one mile long, is located near the intersection of I-29 and Cass County Highway 16, not shown in any Figures. These supplementary channels would have bottom widths of 50 feet.

During operation the FCP alternative is anticipated to produce the following downstream impacts:

- 10 year event maximum impact location downstream stage increase 2.9 inches
- 50 year event maximum impact location downstream stage increase 9.7 inches
- 100 year event maximum impact location downstream stage increase 12.5 inches
- 500 year event maximum impact location downstream stage increase 5.6 inches

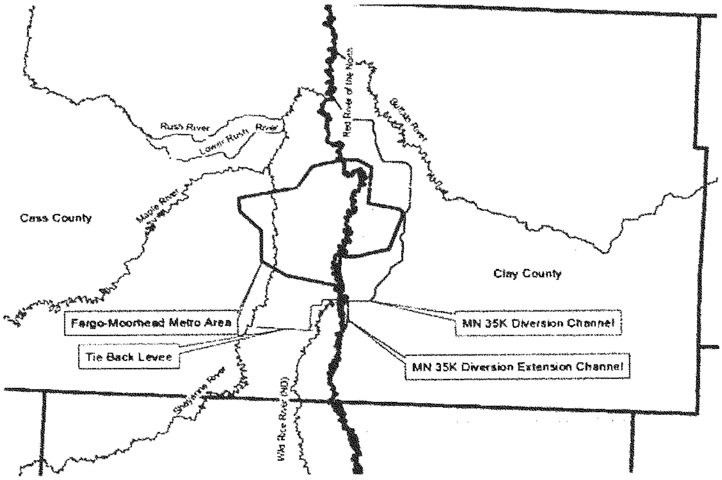


Figure 3. Proposed MN 35K Diversion Channel Alternative

<u>ND 35K Diversion Channel (ND 35K)</u>

This alternative is located west of the Cities of Fargo and Moorhead, with an inlet planned to be constructed south of the Fargo/Moorhead metropolitan area on the Red River approximately 4 miles south of the confluence of the Red River and the Wild Rice River (North Dakota), see Figure 2. The outlet of the diversion channel into the Red River is planned to be constructed north of the Fargo/Moorhead metropolitan area on the Red River approximately 3.5 miles north of the confluence of the Red River and the Sheyenne River.

The diversion channel will have an average bottom width of 300 feet, and internal 1(vertical):7(horizontal) side slopes. The internal side slopes will be increased to 1:5 at highway and railroad intersections. The peak of the spoil piles adjacent to the diversion channel will not exceed 15 feet above existing grade, and external side slopes of the diversion channel will range from 1:7 to 1:10. Total width of the diversion channel construction including; bottom width, internal slopes, and external side slopes will be approximately 2,450 feet. With a total length of approximately 36 miles, the total affected footprint of the diversion channel is approximately 6,560 acres.

A large control structure is proposed to be placed in the Red River channel, approximately 1,600 feet downstream of the diversion channel inlet. The concrete structure will have three gates, each 50 feet wide by 40 feet tall. During normal flows the control structure would be completely open, and during flow events exceeding 9,600 cfs the gates would partially close and the structure would act as a barrier that would back water into the diversion channel. A concrete fish ramp is proposed for construction to allow fish passage up to the 50 year storm event.

The inlet of the connection channel on the west bank of the Red River will consist of a metal sheet pile and rock weir structure. The inlet of the weir structure is set at an elevation which corresponds to the 9,600 cfs flow event at the Fargo USGS gage. A second weir structure will be constructed within the diversion channel on the east bank of the Wild Rice River (ND). This second weir structure will be set at an elevation one foot above the elevation of the first weir.

A gated control structure will be constructed in the Wild Rice River (ND), with two tainter gates (30 feet wide and 25 feet high). The gates will generally be fully open, but during large flow events the gates will be lowered to restrict the flow into the Fargo-Moorhead Metro. Flows would overtop the inlet weir into the diversion channel, on the west bank of the Wild Rice River (ND). Diverted flood waters will flow west and north around the Fargo/Moorhead metropolitan area.

Aqueducts will be built to convey waters in the Sheyenne and Maple Rivers over the diversion channel. The structures will allow the Sheyenne and Maple Rivers to flow through under normal conditions. However, flows exceeding the 2 year storm event within the Sheyenne and Maple will overtop small weir structures and flow through constructed channels into the main diversion channel. The Lower Rush and Rush Rivers will be routed, via drop structures, directly into the diversion channel. The channels of the Lower Rush and Rush Rivers between the diversion channel and downstream to their confluences with the Sheyenne River will be abandoned, and allowed to function as temporary flooded open ditches and as wetland habitat during the drier periods of the growing season. The diversion channel will outlet into the Red River over a weir and rip rap structure.

A three mile tie back levee will need to be constructed to connect the Red River control structure to high ground. The levee will prevent flood waters from flowing over land to north and east into the Fargo/Moorhead metropolitan area.

During operation the ND 35K alternative is anticipated to produce the following downstream impacts:

- 10 year event maximum impact location downstream stage increase 13.9 inches
- 50 year event maximum impact location downstream stage increase 29.4 inches
- 100 year event maximum impact location downstream stage increase 25.4 inches
- 500 year event maximum impact location downstream stage increase 8.4 inches
- Measureable downstream impacts would extend to Thompson, ND and likely into Canada

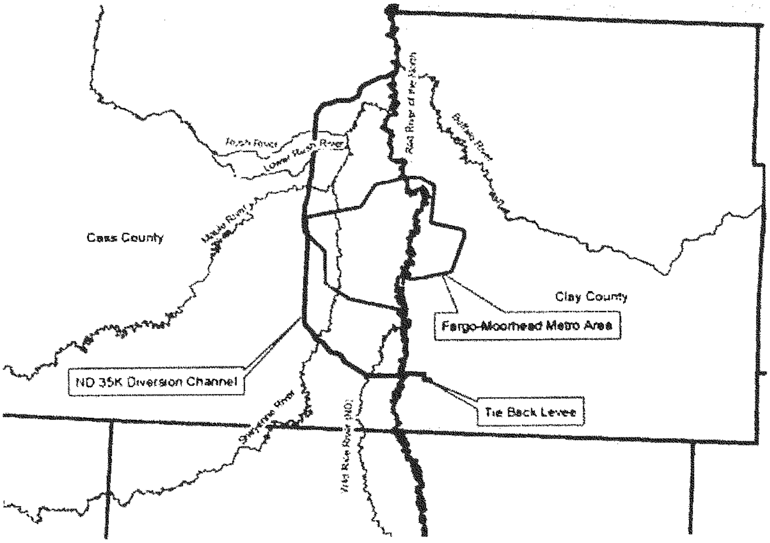


Figure 4. Proposed ND 35K Diversion Channel Alternative

	LLP	FCP	ND 35K Diversion
Length of Channel	36 miles	25 miles	36 miles
Total Width of Channel w/ side slopes	2,200 feet	2,800 feet	2,450 feet
Impact of Primary Diversion Channel	8,054 acres	6,415 acres	6,560 acres
Additional Features Causing Impacts	Upstream staging and storage area	2 secondary diversion channels	Significant rise in downstream Red River stage
Length of Tie Back Levees	10.1	9.9 miles	3.3 miles

Table 1. Comparison of Alternative specifics.

IMPACT ANALYSIS

This Report focuses on potential impacts that would result from the activities involved with the construction, excavation, and operation of the LPP, FCP and ND 35K. Environmental impacts from the LPP, FCP and ND 35K can be separated into two categories: direct impacts, those caused by project construction, and indirect impacts, those associated with project operation.

Direct Impacts of the Locally Preferred Plan

Habitat Loss

Construction and excavation associated with the proposed project will result in the removal or degradation of riparian forest, wetlands (various types), grasslands, and riverine aquatic habitat. The current plan for structure placement and diversion channel route will result in the following impacts; 199.3 acres of forested habitat, 866 acres of wetlands (direct and indirect), and 46 acres of riverine aquatic habitat. Activities resulting in direct impacts include; diversion channel excavation, Red River and Wild Rice River control structure construction, weir construction, levee constructions, Wolverton Creek gated culvert placement, Sheyenne and Maple River crossings construction (aqueducts), and tributary flow diversion and abandonment (Lower Rush and Rush Rivers).

The exact acreage of the various habitats impacted by the project should be calculated once the extent and location of the alternatives are determined.

Fisheries

Construction and excavation within the riverine aquatic habitats could kill adult or juvenile fish. Sediment discharges caused by the aforementioned work could result in adult and juvenile individuals being killed if their gills become filled with sediment, spawn bed abandonment by adult fish, and also the covering of spawning beds with silts and fines resulting in the loss of eggs within the bed. Large sediment loads could also lead to disruptions in foraging success for fish directly downstream of excavation and construction areas within the rivers or areas of bank construction or excavation. Disruption of foraging success could result in the death of juvenile individuals, or prohibit adult fish from spawning due to malnutrition.

Wildlife

Excavation and construction within forested areas, wetlands, and grasslands may be expected to potentially kill or displace nesting adult birds if construction activities occur during the primary nest seasoning (April 1st – August 31st). Abandonment of nests and crushing of eggs within construction and excavation areas is also considered a direct wildlife impact.

Mammal species within the excavation and construction areas will be displaced or killed during project activities. The majority of adult individuals should be mobile enough to move out of the construction/excavation areas prior to being injured or killed by equipment. The exception may be borrowing species that may be injured or killed during excavation activities. Juvenile individuals may not be able to avoid construction and excavation activities resulting in injury or death of certain individuals.

Mussel species within the riverine aquatic habitats may be killed by direct construction or excavation activities within mussel beds. Feeding activities and gill function may be interrupted by large sediment loads during construction and excavation activities. This could result in the death of individuals, or a reduction in or lack of reproduction by adult individuals.

Indirect Impacts of the Locally Preferred Plan

Habitat Loss and Conversation

With additional sediment load and deposition occurring the Red, Wild Rice (ND), Sheyenne, and Maple Rivers will experience some alteration of their bed composition. Also, because of structure placement and reductions in the current regular flood flows through these Rivers, sediments could accumulate and alter the aquatic habitat. This could also result in the need for regular mechanical clean out, which would disturb riparian habitat, aquatic habitat, and fish and wildlife species in the area of the clean out.

Wetlands within the floodplains of the Red, Wild Rice (ND), Sheyenne, and Maple Rivers, and downstream of the proposed structures and diversion channel, may be converted to non-wetland or a drier hydrologic regime if they are heavily influenced hydrologically by regular flood events that currently occur. Wetlands found at the confluences of the Lower Rush and Rush Rivers with the Sheyenne River would likely be converted to non-wetland or a drier hydrologic regime once the Lower Rush and Rush River channels are abandoned.

Fisheries

Movement of fish species within the Red, Sheyenne, and Maple Rivers will be impeded during flood events by structures constructed within the river channels as part of this project. These fish passage impacts will be most noticeable during flood flow events when the gates on the Red River and Wild Rice River control structures are closed and upstream staging of flvoodwater occurs. Fish passage around the control structures will be restricted through the proposed bypass channels up to the 50 year event. Events in excess of a 50 year event will completely stop fish passage through the control structures and proposed bypass channels. Due to long term upstream staging during large flood events the operation of the control structures could result in an almost complete loss of spring fish migration. The operation of the gated culvert on Wolverton Creek will limit fish passage during large flood events. This culvert will be sized according to the currently existing structure, and flows through the existing culvert during flood events may currently limit fish passage due to flow velocities. Flow velocities through the aqueduct structures on the Sheyenne and Maple Rivers become high enough to impede fish passage, primarily for smaller species.

Aquatic organisms displaced by flood events would also be affected by operation of a diversion channel. Fish carried into the diversion may be vulnerable to stranding during lower but more frequent flood events (e.g. 5 or 10 year event) if 1) they are unable to find their way back to the river as water levels recede or 2) the flow dissipates before reconnecting to the Red River. The proposed low flow channel within the diversion channel and fish connectivity step down structures from the Rush and Lower Rush Rivers into the diversion channel will provide possible routes for stranded fish species. Flood-formed scour pools may provide refugia for these fish but they would not survive the winter in such habitat.

Given the scenario above, it appears that a certain degree of fish mortality is unavoidable. The level of mortality is dependant upon the number of fish entering the diversion channel, abundance of water in the channel, and the life stage (juvenile or adult) of the affected individuals.

Wildlife

The upstream staging of flood waters, under 100 year and 500 year events, could prolong the inundation of the lands around the identified bald eagle nest tree approximately 4 miles south of the proposed LPP Red River control structure. It is anticipated that this additional inundation period would not have an effect on adult or fledged juvenile bald eagles. However, the structure stability and longevity of the nest tree could be negatively affected by additional inundation, which could result in the nest tree falling. Bald eagle eggs or unfledged young could be taken should the nest tree fall when either the eggs or the juvenile birds are present. The Service will complete a field survey of all three known bald eagle nests within the project area in the spring 2011. If field conditions and private land access allow, a more detailed analysis of the southernmost bald eagle nest tree will be completed.

Once the project is in the operational phase mussels could be affected by additional direct impacts of operation. In large flood flows the gates on the Red River control structure will partially close, resulting in some deposition of sediment on the upstream side of the structure. A large sediment load could bury and kill individuals. Sediment deposition will also occur on the Wild Rice River (ND) at the location of the proposed control structure. The structures on the Sheyenne and Maple Rivers will restrict flows during flood events, and a portion of the water will be directed into the diversion channel. Water that remains within the river channels will continue to carry a portion of the sediment load, however the quantity and flow of water will be diminished. This will result in additional sediment deposition downstream of the proposed structures. These areas of additional sediment deposition could bury and kill mussels if significant mussel beds are present.

Mussel species dispersal may be restricted during the operational phases of this project. Mussels infest host fish with glychodia, larval stage of mussel, which results in the host fish potentially transporting the glychodia to new suitable aquatic habitat. If fish passage is restricted during flood events potentially infested fish will not be able to disperse the glychodia. Infested fish may also move up the diversion channel and become stranded, or the glychodia could drop off in the diversion channel in unsuitable permanent habitat.

Infested fish moving in the diversion channel could result in the loss of larval stage mussels, and reduce the reproductive success and dispersion of various mussel species.

Direct Impacts of the Federally Comparable Plan

Habitat Loss

Construction and excavation associated with the proposed project will result in the removal or degradation of riparian forest, wetlands (various types), grasslands, and riverine aquatic habitat. The current plan for structure placement and diversion channel route will result in the following impacts; 89 acres of forested habitat, 360 acres of wetlands (direct and indirect), and 10 acres of riverine aquatic habitat. Activities resulting in direct impacts include; diversion channel excavation, Red River control structure construction, weir construction, and levee constructions.

The exact acreage of the various habitats impacted by the project should be calculated once the extent and location of the alternatives are determined.

Fisheries

Construction and excavation within the Red River could kill adult or juvenile fish. Sediment discharges caused by the aforementioned work could result in adult and juvenile individuals being killed if their gills become filled with sediment, spawn bed abandonment by adult fish, and also the covering of spawning beds with silts and fines resulting in the loss of eggs within the bed. Large sediment loads could also lead to disruptions in foraging success for fish directly downstream of excavation and construction areas within the rivers or areas of bank construction or excavation. Disruption of foraging success could result in the death of juvenile individuals, or prohibit adult fish from spawning due to malnutrition.

Wildlife

Excavation and construction within forested areas, wetlands, and grasslands may be expected to potentially kill or displace nesting adult birds if construction activities occur during the primary nest seasoning (April 1st – August 31st). Abandonment of nests and crushing of eggs within construction and excavation areas is also considered a direct wildlife impact.

Mammal species within the excavation and construction areas will be displaced or killed during project activities. The majority of adult individuals should be mobile enough to move out of the construction/excavation areas prior to being injured or killed by equipment. The exception may be borrowing species that may be injured or killed during excavation activities. Juvenile individuals may not be able to avoid construction and excavation activities resulting in injury or death of certain individuals.

Mussel species within the Red River may be killed by direct construction or excavation activities within mussel beds. Feeding activities and gill function may be interrupted by large sediment loads during construction and excavation activities. This could result in the death of individuals, or a reduction in or lack of reproduction by adult individuals.

Indirect Impacts of the Federally Comparable Plan

Habitat Loss and Conversation

With additional sediment load and deposition occurring within the Red River will experience some alteration of bed composition. Also, because of structure placement and reductions in the current regular flood flows through the Red River, sediments could accumulate and alter the aquatic habitat. This could also result in the need for regular mechanical clean out, which would disturb riparian habitat, aquatic habitat, and fish and wildlife species in the area of the clean out.

Wetlands within the floodplain of the Red River, and downstream of the proposed structures and diversion channel, may be converted to non-wetland or a drier hydrologic regime if they are heavily influenced hydrologically by regular flood events that currently occur.

Fisheries

Movement of fish species within the Red River will be impeded by the construction of the control structure within the river channel as part of this project. Fish passage impacts will be noticeable during flood flow events between 9,600 cfs and 25,000 cfs. Fish passage will stop during flows exceeding 25,000 cfs.

Aquatic organisms displaced by flood events would also be affected by operation of a diversion channel. Fish carried into the diversion may be vulnerable to stranding during lower but more frequent flood events (e.g. 5 or 10 year event) if 1) they are unable to find their way back to the river as water levels recede or 2) the flow dissipates before reconnecting to the Red River. Flood-formed scour pools may provide refugia for these fish but they would not survive the winter in such habitat. During planning it has been mentioned that a base flow will be maintained throughout the entire diversion channel. A base flow would be beneficial, but larger species may not be able to effectively move even with a base flow channel.

Given the scenario above, it appears that a certain degree of fish mortality is unavoidable. The level of mortality is dependant upon the number of fish entering the diversion channel, abundance of water in the channel, and the life stage (juvenile or adult) of the affected individuals.

Wildlife

Once the project is in the operational phase mussels could be affected by additional impacts of operation. During flood events the gates on the Red River control structure will close, resulting in deposition of some additional sediment on the upstream side of the structure. A large sediment load could bury and kill individuals. Sediment deposition may also occur downstream of the Red River control structure. Water that remains within the river channel will continue to carry a portion of the sediment load, however the quantity and flow of water will be diminished. These areas of additional sediment deposition could bury and kill mussels if significant mussel beds are present.

Mussel species dispersal may be restricted during the operational phases of this project. Mussels infest host fish with glychodia, larval stage of mussel, which results in the host fish potentially transporting the glychodia to new suitable aquatic habitat. If fish passage is restricted during large flood events potentially infested fish will not be able to disperse the glychodia. Infested fish may also move up the diversion channel and become stranded, or the glychodia could drop off in the diversion channel in unsuitable permanent habitat. Infested fish moving in the diversion channel could result in the loss of larval stage mussels, and reduce the reproductive success and dispersion of various mussel species.

<u>Direct Impacts of the ND 35K Diversion Channel Alternative</u>

Habitat Loss

Construction and excavation associated with the proposed project will result in the removal or degradation of riparian forests, wetlands (various types), grasslands, and riverine aquatic habitat. The current plan for structure placement and diversion channel route will result in the following impacts; 157 acres of forested habitat, 767 acres of wetlands (direct and indirect), and 37 acres of riverine aquatic habitat. Activities resulting in direct impacts include; diversion channel excavation, Red River and Wild Rice River control structure construction, weir construction, levee constructions, Wolverton Creek gated culvert placement, Sheyenne and Maple River crossings construction (aqueducts), and tributary flow diversion and abandonment (Lower Rush and Rush Rivers).

The exact acreage of the various habitats impacted by the project should be calculated once the extent and location of the alternatives are determined.

Fisheries

Construction and excavation within the riverine aquatic habitats could kill adult or juvenile fish. Sediment discharges caused by the aforementioned work could result in adult and juvenile individuals being killed if their gills become filled with sediment, spawn bed abandonment by adult fish, and also the covering of spawning beds with silts and fines resulting in the loss of eggs within the bed. Large sediment loads could also lead to disruptions in foraging success for fish directly downstream of excavation and construction areas within the rivers or areas of bank construction or excavation. Disruption of foraging success could result in the death of juvenile individuals, or prohibit adult fish from spawning due to malnutrition.

Wildlife

Excavation and construction within forested areas, wetlands, and grasslands may be expected to potentially kill or displace nesting adult birds if construction activities occur during the primary nest seasoning (April 1st – August 31st). Abandonment of nests and crushing of eggs within construction and excavation areas is also considered a direct wildlife impact.

Mammal species within the excavation and construction areas will be displaced or killed during project activities. The majority of adult individuals should be mobile enough to move out of the construction/excavation areas prior to being injured or killed by equipment. The exception may be borrowing species that may be injured or killed during excavation activities. Juvenile individuals may not be able to avoid construction and excavation activities resulting in injury or death of certain individuals.

Mussel species within the riverine aquatic habitats may be killed by direct construction or excavation activities within mussel beds. Feeding activities and gill function may be interrupted by large sediment loads during construction and excavation activities. This could result in the death of individuals, or a reduction in or lack of reproduction by adult individuals.

<u>Indirect Impacts of the ND 35K Diversion Channel Alternative</u>

Habitat Loss and Conversation

With additional sediment load and deposition occurring the Red, Wild Rice (ND), Sheyenne, and Maple Rivers will experience some alteration of their bed composition. Also, because of structure placement and reductions in the current regular flood flows through these Rivers, sediments could accumulate and alter the aquatic habitat. This could also result in the need for regular mechanical clean out, which would disturb riparian habitat, aquatic habitat, and fish and wildlife species in the area of the clean out.

Wetlands within the floodplains of the Red, Wild Rice (ND), Sheyenne, and Maple Rivers, and downstream of the proposed structures and diversion channel, may be converted to non-wetland or a drier hydrologic regime if they are heavily influenced hydrologically by regular flood events that currently occur. Wetlands found at the confluences of the Lower Rush and Rush Rivers with the Sheyenne River would likely be converted to non-wetland or a drier hydrologic regime once the Lower Rush and Rush River channels are abandoned.

Fisheries

Movement of fish species within the Red, Wild Rice, Sheyenne, and Maple Rivers will be impeded by structures constructed within the river channels as part of this project. These fish passage impacts will be noticeable during larger flood flow events when the gates on the Red River and Wild Rice control structures are closed, and when flow velocities through the structures on the Sheyenne and Maple Rivers become high enough to impede fish passage, primarily for smaller species.

Aquatic organisms displaced by flood events would also be affected by operation of a diversion channel. Fish carried into the diversion may be vulnerable to stranding during lower but more frequent flood events (e.g. 5 or 10 year event) if 1) they are unable to find their way back to the river as water levels recede or 2) the flow dissipates before reconnecting to the Red River. Flood-formed scour pools may provide refugia for these fish but they would not survive the winter in such habitat. During planning it has been mentioned that a base flow will be maintained throughout the entire diversion channel. A base flow would be beneficial, but larger species may not be able to effectively move even with a base flow channel.

Given the scenario above, it appears that a certain degree of fish mortality is unavoidable. The level of mortality is dependant upon the number of fish entering the diversion channel, abundance of water in the channel, and the life stage (juvenile or adult) of the affected individuals.

Wildlife

Once the project is in the operational phase mussels could be affected by additional direct impacts of operation. In large flood flows the gates on the Red River control structure will close, resulting in deposition of sediment on the upstream side of the structure. A large sediment load could bury and kill individuals. Sediment deposition will also occur on the Wild Rice River (ND) at the point of confluence with the proposed diversion channel and downstream of this point. The structures on the Sheyenne and Maple Rivers will restrict flows during flood events, and a portion of the water will be directed into the diversion channel. Water that remains within the river channels will continue to carry a portion of the sediment load, however the quantity and flow of water will be diminished. This will result in additional sediment deposition downstream of the proposed structures. These areas of additional sediment deposition could bury and kill mussels if significant mussel beds are present.

Mussel species dispersal may be restricted during the operational phases of this project. Mussels infest host fish with glochidia, larval stage of mussel, which results in the host fish potentially transporting the glochidia to new suitable aquatic habitat. If fish passage is restricted during large flood events potentially infested fish will not be able to disperse the glochidia. Infested fish may also move up the diversion channel and become stranded, or the glochidia could drop off in the diversion channel in unsuitable permanent habitat. Infested fish moving in the diversion channel could result in the loss of larval stage mussels, and reduce the reproductive success and dispersion of various mussel species.

PROPOSED MINIMIZATION AND MITIGATION ACTIVITIES

1. Construction of two or more fish bypass channels is proposed to improve fish passage around the Red River and Wild Rice control structures during large flow events when the gates will be closed. (LPP and ND 35K Alternatives)
   a. Bypass channels will be 40 feet wide and a total length of 900 feet consisting of a series of pools and riffles.
2. Completion of Drayton Dam fish passage to improve connectivity and off-set operational impacts to fish passage at the Red River and Wild Rice River control structures. (LPP Alternative)
3. Stream restoration and implementation of fish passage at existing dams with the Red River and it's tributaries (All Alternatives)
4. Construction of two bypass channels is proposed to improve fish passage around the Red River control structure during large flow events when the gates will be closed. (FCP Alternative)
   a. Bypass channels will be 40 feet wide and a total length of 900 feet consisting of a series of pools and riffles.
5. A natural substrate will be maintained under the Red River and Wild Rice control structures and aqueduct structures on the Sheyenne and Maple Rivers to allow for complex flow regimes, which will allow for better fish passage through the structures. (All Alternatives as appropriate)
6. Maintain a meandering base flow channel within the diversion channel to assist in minimizing fish stranding. (All Alternatives)
7. Allow the bottom of the diversion channel function as aquatic and seasonal wetland habitats to provide habitat to local wildlife. (All Alternatives)
8. The abandoned Lower Rush and Rush River channels to function as seasonal wetlands and aquatic habitats to benefit local wildlife species. (LPP and ND 35K Alternatives)
9. All wetland impacts will be replaced at a ratio to meet or exceed the Compensatory Mitigation Standards of the Clean Water Act, Section 404 Permit Program. State wetland laws will also be satisfied. (All Alternatives)
10. Impacted forested areas will be replaced at a 1:1 ratio. (All Alternatives)
11. Grassland habitat impacts will be offset by the reconstruction of native prairie on the inside slope of the diversion channel following construction. (All Alternatives)
12. Adaptive Management measures will be implemented for the proposed project, which will entail various monitoring, assessments, operational changes, and additional mitigation if necessary. (All Alternatives)

RECOMMENDATIONS PROVIDED IN THE DRAFT FWCA REPORT

1. Determine wetland acreage to be impacted directly or indirectly by the proposed project, and assess the functions and values of individual wetlands with an established method of assessment, such as the Minnesota Rapid Assessment Method (MnRAM).
    a. This recommendation was provided by the Service in 2010, and has been completed by the Corps.
    b. Corps responded in the DEIS
    c. Corps staff has completed desktop reviews and on-site field work (July 2010).
2. Provide compensatory mitigation for all wetland impacts in accordance with the standards specified for a Section 404 Permit under the Clean Water Act. A final wetland mitigation plan should be coordinated with the Service and Corps Regulatory Project Manager.
    a. Corps responded in the DEIS.
    b. A low flow sinuous channel is being included in the designs of the diversion channel, which will assist in maintaining the hydrology of areas of seasonally flooded basins, wet meadow, and shallow marsh wetland habitats within the diversion channel. These areas are anticipated to become established with natural vegetation, which will result in water quality, wildlife habitat, and species diversity improvements within the area.
    c. Functional offsets for project wetland impacts are approximately; 1,515 acres (FCP), 1,527 acres (ND35K), and 1,450 acres (LPP). Resulting in functional replacement ratios as follows; 1.67:1 (FCP), 1.7:1 (ND35K), and 1.45:1 (LPP).
3. Wetlands within the currently active floodplains of the Red, Wild Rice (ND), Sheyenne, Lower Rush, and Rush Rivers, downstream of the proposed structures and the diversion channel crossings or channel abandonments should be monitored for a 10 year period following the beginning of project flood reduction operations. This monitoring should focus on hydrologic impacts to the wetlands, wetland type conversions, and loss of wetlands. (All Alternatives as appropriate)
    a. Corps responded in the DEIS.
    b. Corps staff does not anticipate any adverse impacts to the existing wetlands in these areas as the more frequent event flows will be passing through the project as they currently do. The smaller more frequent events along with direct precipitation are what sustain these wetlands.
4. Utilize the data provided by the proposed geomorphic and biotic surveys within the potentially affected reaches of Red, Wild Rice (ND), Sheyenne, Maple, Lower Rush, and Rush Rivers to assess the quality of existing habitats and quantify impacts to the fish and wildlife resources.
    a. Corps concurred in their responded in the DEIS.
    b. This data will not be available at the time of completing the Final EIS (FEIS), but it will be utilized as part of the Corps adaptive management to

establish a baseline to verify project impacts and used for comparison regarding mitigation effectiveness.

5. Utilize native plant species in all aspects of mitigation, reconstruction, and replanting involved with the project.
   a. Corps responded in the DEIS.
   b. Native plant species will be used for all project mitigation and reseeding excavation areas.
6. Avoid impacts to migratory bird nesting habitats (woodlands, grasslands, and wetlands) during the primary nesting season, April 1st to August 31st, to the greatest extent that is feasible.
   a. Corps responded in the DEIS.
   b. Nesting habitat for some species of migratory birds may be disturbed or removed during construction. Vegetation clearing activities will be completed, to the greatest extent possible, to avoid affecting nesting individuals. Some limited incidental take of individuals may occur during construction. The Corps does not expect any limited take would have a long lasting effect on the affected migratory bird species.
7. Provide equal mitigation (1:1) for lands currently enrolled in state or federally funded restoration or conservation programs that will be impacted by the proposed project.
   a. Corps responded in the DEIS.
   b. Currently none of these land types have been identified as being impacted lands by the project construction or operation. Adverse impacts to lands enrolled in State or Federally funded restoration or conservation programs will be mitigated.
8. Raptor nest surveys should be conducted every spring to determine the presence of existing or new nests that may be affected by the project construction and excavation activities. Surveys should be completed annually prior to "leaf out" until the project construction is complete.
   a. Corps concurred in their response in the DEIS.
9. Follow the Service's National Bald Eagle Management Guidelines to minimize the likely-hood that the proposed project will affected any bald eagles nesting in the Fargo/Moorhead Project Area.
   a. Corps concurred in their response in the DEIS.
10. Allocate funding toward and coordinate with the Service to develop large scale wetland restoration areas within the upstream reaches of the Red River basin, which could help attenuate flood waters in the smaller more frequent storm events.
    a. Corps responded in the DEIS.
    b. The Fargo-Moorhead diversion is being designed to address extremely large flood events in which wetland restoration would provide little additional benefit. Flood storage upstream may help reduce flows from smaller more frequent flood events and may reduce the diversion's frequency of operation, but the design of diversion project features would not be affected.

c. The Corps currently has two on-going studies, Fargo-Moorhead Upstream Study and the Red River Basin Wide Feasibility Study, which could investigate the potential benefits and costs of large-scale wetland restoration in the upper watershed. Investigations related to restoration would need to be coordinated and supported by the non-federal sponsors for each of these projects.

11. A survey for blooming western prairie fringed orchids will be coordinated with the Service, and will be completed at the identified location within the upstream staging area in Richland County, ND.
    a. Corps concurred in their response in the DEIS.

	LPP	FCP	ND 35K
Total Wetland Impacts	1,161 acres	972 acres	1,058 acres
Forest Impacts	199.3	89 acres	157 acres
Aquatic Riverine Impacts	46 acres	.10 acres	37 acres
Red River Fish Passage Impacts	Yes	Yes	Yes
Red River Tributary Fish Passage Impacts	Yes	No	Yes
# of Rivers Impacted	6	1	6
Federal Threatened and Endangered Species Impacted	No	No	No
Bald Eagles Impacted	Unknown	Unknown	Unknown
Red River Sedimentation Impacts	Yes	Yes	Yes
Red River Tributary Sedimentation Impacts	Yes	No	Yes

Table 2. Impact Analysis Comparison of Alternatives.

SUMMARY

River channel morphology is largely defined by the frequency and intensity of floods. Flood events and the intensity of their environmental effects are naturally unpredictable. The LPP, FCP, and ND 35K alternatives involve the construction and operation of a control structure within the Red River. Operation of the Red River control structure and the associated diversion channel will, reduce the magnitude of flood flows, into the Fargo – Moorhead Metro Area. This reduction in peak flow could affect sediment loads and deposition within the Red River. The LPP and ND 35K alternatives also includes a second control structure within the Wild Rice (ND) River, diversion channel crossing structures on the Sheyenne and Maple Rivers, and the abandonment of portions of the Lower Rush and Rush Rivers.

All proposed alternatives will result in direct and indirect wetland impacts. The LPP and ND 35K Alternative will impact more wetlands then the FCP alternative. There will be some wetland loss through direct excavation and/or fill of wetlands during channel, levee, and structure construction. Riparian wetlands along the river corridors are likely to incur some indirect impacts as the change in flood elevations may result in changes to the hydrologic inputs to some of these wetlands. The exact extent of wetland impacts cannot be quantified at this time as the footprint and design of the project have not been finalized. Wetland mitigation needed to address these issues should be carried out concurrent with project construction.

All alternatives may impact fish passage, fish spawning areas, mussel beds, and terrestrial wildlife habitat during construction, excavation, operation, and maintenance of the proposed Fargo-Moorhead Flood Reduction Project. The LPP and ND 35K Alternative as proposed will result in greater ecological impacts, then the FCP Alternative. The LPP and ND 35K Alternative impacts are greater due to the higher number of rivers affected by the diversion channel, greater potential for fish connectivity impediment during operation, and wildlife habitat disturbance. Outside of work within the Red River and the adjacent riparian habitat the FCP alternative primarily affects agricultural lands.

With regard to the Fargo-Moorhead Flood Risk Management Project the Service recommends selection of the FCP Alternative (Minnesota Diversion Route) due to the reduced ecological impacts associated with this alternative. The Service also recommends that the Corps continue to investigate, and implement where practicable, large – scale wetland restoration in the upper portion of the Red River Watershed. As wetland restorations within the upper portion of the watershed may potentially reduce the frequency and/or duration of operation of the proposed control structure, which in turn could improve fish passage through the Red River structure.

The Corps should stay in close contact with Service staff during construction of the selected project alternative to address any future ecological issues that may arise during the progression of the project. Including but not limited to; new listings under the ESA, newly identified locations of species protected under the ESA, MBTA related issues, newly constructed or identified bald eagle nests, etc. Development of a Scope of Work and binding Agreement between the Corps and Service for the Service to be involved with any and all future Environmental Assessment documentation associated with the Fargo-Moorhead Flood Risk Management Project seems warranted under the Fish and Wildlife Coordination Act.

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APPENDIX 1

FISH AND WILDLIFE RESOURCES OF THE RED RIVER

Table 1. Fish species present in the Red River drainage. (Aadland et al. 2005)

Common Name	Scientific Name
Chestnut lamprey	*Ichthyomyzon castaneus*
Silver lamprey	*Ichthyomyzon unicuspis*
White sucker	*Catostomus commersoni*
Silver redhorse	*Moxostoma anisurum*
Golden redhorse	*Moxostoma erythrurum*
Shorthead redhorse	*Moxostoma macrolepidotum*
Greater redhorse	*Moxostoma valenciennesi*
Spotfin shiner	*Cyprinella spiloptera*
Carp	*Cyprinus carpio*
Brassy Minnow*	*Hybognathus hankinsoni*
Common shiner	*Luxilus cornutus*
Bowfin	*Amia calva*
Emerald shiner	*Notropis atherinoides*
Bigmouth shiner	*Notropis dorsalis*
Blackchin shiner*	*Notropis heterodon*
Blacknose shiner*	*Notropis heterolepis*
Sand shiner	*Notropis stramineus*
River shiner	*Notropis blennius*
Spottail shiner	*Notropis hudsonius*
Carmine shiner*	*Notropis percobromus*
Northern redbelly dace*	*Phoxinus eos*
Fathead minnow	*Pimephales promelas*
Western blacknose dace*	*Rhinichthys obtusus*
Longnose dace	*Rhinichthys cataractae*
Creek chub	*Semotilus atromaculatus*
Black bullhead	*Ameiurus melas*
Yellow bullhead	*Ameiurus natalis*
Brown bullhead	*Ameiurus nebulosus*
Channel catfish	*Ictalurus punctatus*
Tadpole madtom	*Noturus gyrinus*
Central Mudminnow	*Umbra limi*
Northern pike	*Esox Lucius*
Trout-perch	*Percopsis omiscomaycus*
Rock bass	*Ambloplites rupestris*
Pumpkinseed*	*Lepomis gibbosus*
Bluegill	*Lepomis macrochirus*
Largemouth bass*	*Micropterus salmoides*
Black crappie	*Pomoxis nigromaculatus*
White Crappie	*Pomoxis annularis*
Johnny darter	*Etheostoma nigrum*
Yellow perch	*Perca flavescens*
Blackside darter	*Percina maculate*
Logperch	*Percina caprodes*
Sauger	*Stizostedion canadense*
Walleye	*Stizostedion vitreum*
Freshwater drum	*Aplodinotus grunniens*

Table 1 cont'd. Fish species present in the Red River drainage. (Aadland et al. 2005)

Common Name	Scientific Name
Goldeye	*Hiodon alosoides*
Mooneye	*Hiodon tergisus*
Rainbow trout*	*Oncorhynchus mykiss*
Quillback	*Carpiodes cyprinus*
Bigmouth Buffalo	*Ictiobus cyprinellus*
Goldfish	*Carassius auratus*
Silver chub	*Macrhybopsis margarita*
Hornyhead chub	*Nocomis biguttatus*
Golden shiner	*Notemigonus chrysoleucas*
Bluntnose minnow	*Pimephales notatus*
Flathead chub	*Platygobio gracilis*
Stonecat	*Noturus flavus*
Muskellunge	*Esox masquinongy*
Rainbow smelt	*Osmerus mordax*
Banded killifish	*Fundulus diaphanous*
Burbot	*Lota lota*
White bass	*Morone chrysops*
Green sunfish	*Lepomis cyanellus*
Orangespotted sunfish	*Lepomis humilis*
Smallmouth bass	*Micropterus dolomieu*
Iowa Darter	*Etheostoma caeruleum*
Lake Sturgeon	*Acipenser fulvescens*

*Found in the tributaries to the Red River, but not in the main stem of the Red River.

Table 2. Mammals of the Fargo-Moorhead Project Area.

Common Name	Common Name
Grey fox	Fox squirrel
Red fox	Red squirrel
Raccoon	Northern flying squirrel
Striped skunk	Beaver
Coyote	Muskrat
Masked shrew	Deer mouse
Pygmy shrew	White-footed mouse
Short-tailed shrew	Southern red-backed vole
Star-nosed mole	Meadow vole
Little brown myotis	Prairie vole
Big brown bat	Norway rat
Red bat	House mouse
Eastern Cottontail Rabbit	Meadow jumping mouse
White-tailed jackrabbit	Plains pocket mouse
Eastern chipmunk	Ermine
Least chipmunk	Long-tailed weasel
Woodchuck	Least weasel
Thirteen-lied ground squirrel	Gray wolf
Franklin's ground squirrel	River otter
Eastern gray squirrel	Mink
White-tailed deer	Badger
Opossum	

Table 3. Amphibians and Reptiles of Clay County, Minnesota.

Common Name (Amphibians)	Common Name (Reptiles)
Northern leopard frog	Common garter snake
Wood frog	Redbelly snake
Gray treefrog	Plains hog nosed snake
Western chorus frog	Plains garter snake
Boreal chorus frog	Smooth green snake
American toad	Snapping turtle
Canadian toad	Painted turtle
Great plains toad	Prairie skink
Tiger salamander	

Table 4. Mussels in the Fargo-Moorhead Area. (Sietman 2008)

Common Name	Scientific Name
Fatmucket	*Lampsilis siliquoidea*
Threeridge	*Amblema plicata*
Giant floater	*Pyganodon grandis*
Black Sandshell	*Ligumia recta*

Table 5. Breeding Birds of Clay County, Minnesota. (MN DNR)

Common Name	Common Name
Canada goose	Sedge wren
Wood duck	Eastern bluebird
Mallard	Veery
Blue winged teal	American robin
Ring necked duck	Gray catbird
Pied billed grebe	Brown thrasher
Red necked grebe	European starling
Double crested cormorant	Cedar waxwing
Great blue heron	Yellow warbler
Northern harrier	Chestnut sided warbler
Red tailed hawk	American redstart
Killdeer	Ovenbird
Upland sandpiper	Common yellowthroat
Wilson's snipe	Scarlet tanager
Black tern	Chipping sparrow
Rock pigeon	Clay colored sparrow
Mourning dove	Field sparrow
Great horned owl	Vesper sparrow
Chimney swift	Savannah sparrow
Ruby throated hummingbird	Grasshopper sparrow
Red bellied Woodpecker	Le Conte's sparrow
Yellow bellied sapsucker	Song sparrow
Downy woodpecker	Swamp sparrow
Hairy woodpecker	Rose breasted grosbeak
Northern flicker	Indigo bunting
Eastern wood-pewee	Bobolink
Alder flycatcher	Red winged blackbird
Willow flycatcher	Western meadowlark
Least flycatcher	Yellow headed blackbird
Eastern phoebe	Brewer's blackbird
Great crested flycatcher	Common grackle
Western kingbird	Brown headed cowbird
Eastern kingbird	Baltimore oriole
Yellow throated vireo	American goldfinch
Warbling vireo	Baird's sparrow
Red eyed vireo	Bald eagle
Blue jay	Burrowing owl
American crow	Chestnut collared longspur
Horned lark	Greater prairie chicken
Tree swallow	Henslow's sparrow
Bank swallow	Loggerhead shrike
Barn swallow	Marbled godwit
Black capped chickadee	Nelson's sharp tailed sparrow
White breasted nuthatch	Sprague's pipit
House wren	Trumpeter swan
Wilson's phalarope	Yellow rail
Northern cardinal	

Attachment 3

Fargo-Moorhead Metro

Final Feasibility Report and Environmental Impact Statement

July 2011

Cultural Resources Programmatic Agreement

**PROGRAMMATIC AGREEMENT
AMONG THE U.S. ARMY CORPS OF ENGINEERS, ST. PAUL DISTRICT,
THE NORTH DAKOTA STATE HISTORIC PRESERVATION OFFICER, AND
THE MINNESOTA STATE HISTORIC PRESERVATION OFFICER
REGARDING
THE FARGO-MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT,
CASS COUNTY, NORTH DAKOTA AND CLAY COUNTY, MINNESOTA**

Final – 2011

WHEREAS, the St. Paul District, U.S. Army Corps of Engineers (Corps) is conducting a feasibility study of flood risk management measures for the cities of Fargo, Cass County, North Dakota and Moorhead, Clay County, Minnesota; and

WHEREAS, the Corps is considering the following flood risk management measures for the Fargo Moorhead metropolitan area and adjacent county areas (Figures 1 and 2): (1) a diversion channel capable of passing 20,000 cfs on the west (North Dakota) side of the Red River of the North along with upstream storage and staging areas, (Locally Preferred Plan [LPP] alternative) and (2) a diversion channel capable of passing 35,000 cfs on the east (Minnesota) side of the Red River of the North (Federally Comparable Plan [FCP] alternative).

WHEREAS, the necessary cultural resources investigations, evaluations, and coordination for compliance with Section 106 of the National Historic Preservation Act of 1966, as amended, cannot be completed by the Corps or its agent prior to starting the design stage of the Fargo-Moorhead Metropolitan Flood Risk Management Project (Project); and

WHEREAS, the Corps has established the Project's Area of Potential Effects (APE), as required by 36 CFR § 800.4(a)(1) and defined in section 800.16(d), as consisting of the footprint of the selected diversion plan including the diversion channel alignment, its associated tieback levee(s), associated construction work areas, construction staging areas, borrow areas, and disposal areas, as well as associated upstream water storage and water staging areas, project-related floodproofing locations, and the viewshed to one-half mile from the diversion channel's centerline, to one-eighth mile from the tieback levee's centerline, and to one-eighth mile outside the storage area boundary levee's centerline; and

WHEREAS, the Corps has determined that the Project may have effects on historic properties within the APE and has consulted with the Advisory Council on Historic Preservation (Advisory Council) pursuant to section 800.2(b) of the regulations (36 CFR Part 800) implementing Section 106 of the National Historic Preservation Act (16 U.S.C. § 470f), and the Advisory Council has declined to participate in the Programmatic Agreement for this Project; and

WHEREAS, the City of Fargo, North Dakota, and the City of Moorhead, Minnesota (Cities), as the non-Federal sponsors for the Project, have participated in consultation on the Project's flood risk management measures and have been invited to concur in this Programmatic Agreement as consulting parties; and

WHEREAS, Cass County in North Dakota and Clay County in Minnesota are also interested parties and have been invited to participate in consultation on the Project's flood risk management measures and to concur in this Programmatic Agreement as consulting parties; and

WHEREAS, the Corps' St. Paul District Engineer initially contacted the chairman or chairwoman of the Sisseton-Wahpeton Oyate, the White Earth Band of Minnesota Chippewa, the Leech Lake Band of Ojibwe, the Turtle Mountain Band of Chippewa, the Upper Sioux Community of Minnesota, the Lower Sioux Indian Community, the Spirit Lake Tribe, and the Red Lake Band of Chippewa Indians, by letter dated April 8, 2009; initially contacted the chairman or chairwoman of the Bois Forte Band of Chippewa Indians, the Three Affiliated Tribes (Mandan, Hidatsa and Arikara Nation), the Northern Cheyenne Tribe, the Standing Rock Sioux Tribe, the Yankton Sioux Tribe, and the Assiniboine and Sioux Tribes of the Fort Peck Indian Reservation, by letter dated October 7, 2010; and initially contacted the chairman of the Crow Creek Sioux Tribe and the Flandreau Santee Sioux Tribe, by letter dated May 2011, to determine these tribes' interest in the Project, particularly regarding potential Project effects on properties important to their history, culture, or religion, including traditional cultural properties, and the Corps will consult with any of these tribes interested in this Project; and

WHEREAS, opinions and comments on the Project and its alternative alignments have been and will be solicited through comment periods on the Environmental Impact Statement and public meetings, including those held to comply with the National Environmental Policy Act (NEPA);

NOW THEREFORE, the Corps, the North Dakota State Historic Preservation Officer (SHPO), and the Minnesota State Historic Preservation Officer agree that upon filing this Programmatic Agreement (PA) with the Advisory Council on Historic Preservation, the Corps will implement the following stipulations in order to comply with Section 106 of the National Historic Preservation Act, as amended, with respect to the Project.

STIPULATIONS

The Corps will ensure that the following measures are carried out prior to the start of construction on Project flood risk management features at the cities of Fargo, Cass County, North Dakota, and Moorhead, Clay County, Minnesota:

A. The Corps will ensure that archeologists, historians, and architectural historians meeting the professional qualification standards given in the Secretary of the Interior's *Standards and Guidelines for Archeology and Historic Preservation* will conduct or directly supervise all cultural resources identification, evaluation, and mitigation related to this Project, to include archeological surveys and testing, historic structure inventories and evaluation, and data recovery and documentation mitigation, and be permitted in North Dakota pursuant to North Dakota Century Code Section 55-03-01 and in Minnesota pursuant to Minnesota Statutes Sections 138.31 to 138.42.

B. Literature and Records Search – Prior to conducting any cultural resources fieldwork, the Corps or its contractors or the Cities' contractors shall at a minimum consult the site files, previous survey reports, and other documents at the Historic Preservation Division of the State Historical Society of North Dakota at Bismarck and at the State Historic Preservation Office at the Minnesota Historical Society in St. Paul, for information on previously recorded cultural resources sites, site leads, and previously surveyed areas in the Project's APE.

C. Phase I Cultural Resources Investigation – The Corps or its contractors or the Cities' contractors will conduct a Phase I survey of all previously uninventoried project areas in order to locate any cultural resources (prehistoric, historic, and architectural) within the Project's APE. The cultural resources investigation will be an intensive, on-the-ground study of the area sufficient to determine the number and extent of the resources present and their relationships to Project features. The archeological investigations will take into account the unique geomorphology of the Red River Valley, and the potential for deeply buried soils. The survey also will consider and address visual effect impacts of proposed above-ground components (e.g., tieback levees) to cultural resources and landscapes within the project APE.

D. Phase II Testing and Evaluation – The Corps or its contractors or the Cities' contractors will evaluate the National Register of Historic Places eligibility of all cultural resources sites or structures over 50 years old located within the APE. Evaluation shall include subsurface testing using one-meter by one-meter excavation units to determine the information potential of prehistoric and historic archeological sites and archival research for historic archeological and architectural sites. The Corps will request the concurrence of the North Dakota SHPO or Minnesota SHPO, whichever is applicable, in determining each such site or structure's eligibility or non-eligibility to the National Register.

E. Phase III Mitigation – The Corps will avoid or minimize Project-related adverse effects to historic properties (National Register of Historic Places-listed or eligible sites, structures, buildings, districts, or objects) to the extent practicable. Where adverse effects due to the Project are not avoidable, the Corps will coordinate and implement a Memorandum of Agreement (MOA) with the North Dakota and/or Minnesota SHPO and the other consulting parties, any affected Indian tribes, and other interested parties, as applicable, to mitigate the adverse effects.

F. Burials – If any human burials are encountered during the cultural resources field work or Project construction, the Corps and its contractors and the Cities' contractors will comply with the Native American Graves Protection and Repatriation Act (NAGPRA) for federal or tribal lands, or with North Dakota Century Code Section 23-06-27, "Protection of Human Burial Sites, Human Remains, and Burial Goods," and North Dakota Administrative Code Chapter 40-02-03, "Protection of Prehistoric and Historic Human Burial Sites, Human Remains, and Burial Goods," for all other lands in North Dakota, or with Minnesota Statutes Section 307.08, Minnesota Private Cemeteries Act, for all other lands in Minnesota, whichever is applicable.

G. Traditional Cultural Properties – The Corps or its contractor will consult and coordinate with the tribes listed in the 8th WHEREAS clause above to identify sites of traditional religious or cultural importance to the tribe or their members within the Project area. Such sites shall be avoided or adverse effects to them minimized to the extent practicable and the remaining effects mitigated per a MOA developed between the Corps, the applicable SHPO, and the affected tribe(s). Specific cultural and locational information on Traditional Cultural Properties (TCPs) is considered sensitive information by the tribes. Only general descriptions and general locational information will be released to the general public, unless otherwise required by law.

H. Curation – The Corps or its contractors or the Cities' contractors shall ensure that all materials and records resulting from the survey, evaluation, and data recovery or mitigation conducted for the Project, or recovered during Project construction, will be curated in accordance with 36 CFR Part 79, "Curation of Federally-Owned and Administered Archeological Collections" at a facility within the state of North Dakota or the state of Minnesota, depending upon the location of the cultural resources fieldwork or site(s) being investigated, unless the private landowner wishes to retain ownership of artifacts recovered from his/her land.

I. Construction Monitoring – In order to minimize or avoid construction delays, monitoring of construction earthwork by a qualified professional archeologist is recommended at certain Project locations, such as river terraces, oxbows, and floodplains, which have a high potential for deeply buried archeological resources that cannot be reached by normal archeological subsurface testing methods. Any monitoring at a TCP location will also have a knowledgeable tribal representative present or available. The Corps will determine which specific locations should have construction monitoring based upon the results of the Phase 1 cultural resources investigation and the TCP study (Stipulations C and G above) and available soils and geomorphology information.

J. Discoveries During Project Implementation – Should an unidentified site or property that may be eligible for inclusion in the National Register be discovered during Project construction, the Corps will cease all work in the vicinity of the discovered property until it can be evaluated pursuant to guidelines in Stipulation D of this Programmatic Agreement. If the property is determined to be eligible, the Corps shall comply with the provisions of Stipulation E above. Project actions which are not in the area of the discovery may proceed while the consultation and any necessary evaluation and mitigation work is conducted.

K. Reports – The Corps shall ensure that draft and final reports resulting from actions pursuant to the Stipulations of this Programmatic Agreement will be provided to the appropriate SHPOs, the non-Federal sponsors, and upon request, to other parties to this agreement. All parties will have 30 days to review and comment on any draft reports furnished to them.

ADMINISTRATIVE PROCEDURES

L. Dispute Resolution – Should the North Dakota SHPO, the Minnesota SHPO, or a concurring party to the PA object to any plans, documents, or reports prepared under the terms of this PA within 30 days after receipt, the Corps shall consult with the party to resolve the objection. If the Corps determines that the objection cannot be resolved, the Corps shall forward all documentation relevant to the dispute to the Advisory Council. Any recommendation or comment provided by the Advisory Council will be understood to pertain only to the subject of the dispute. The Corps' responsibility to carry out all actions under this PA that are not the subject of the dispute will remain unchanged.

M. <u>Amendments</u> – Any party to this PA may request that it be amended, whereupon the parties will consult to consider such amendment. The PA may only be amended with the written concurrence of all parties who have signed the PA.

N. <u>Anti-Deficiency Provision</u> – All obligations on the part of the Corps under this PA shall be subject to the appropriation, availability and allocation of sufficient funds to the St. Paul District for such purposes.

O. <u>Termination</u>

1. Proof of compliance with the Stipulations to the satisfaction of the Corps, the North Dakota SHPO and the Minnesota SHPO will constitute termination of this Programmatic Agreement.

2. If the terms of this PA have not been implemented fifteen years after execution, this agreement will be null and void. In such an event, the Corps shall notify the North Dakota SHPO and the Minnesota SHPO of its expiration, and if appropriate, shall re-initiate review of the undertaking in accordance with 36 CFR part 800.

3. Any signatory party to this PA may withdraw from it by providing thirty (30) days notice to the other parties, provided that the parties will consult during the period prior to withdrawal to seek agreement on amendments or other actions that would avoid withdrawal. In the event of termination, or withdrawal, the Corps will comply with federal regulation 36 CFR part 800, Protection of Historic Properties.

Execution of this Programmatic Agreement, its subsequent filing with the Advisory Council, and implementation of its Stipulations evidences that the Corps has taken into account the effects of the Project on National Register listed or eligible historic properties, and has satisfied its Section 106 responsibilities for all aspects of this undertaking.

ST. PAUL DISTRICT, U.S. ARMY CORPS OF ENGINEERS

BY: ______________________ Date: 29 June 2011
~~LTC. Kendall A. Bergmann,~~ Acting District Engineer
Judith L. A. DesHarnais

NORTH DAKOTA STATE HISTORIC PRESERVATION OFFICER

BY: ______________________ Date: July 13, 2011
Merlan E. Paaverud, Jr., State Historic Preservation Officer

MINNESOTA STATE HISTORIC PRESERVATION OFFICER

BY: ______________________ Date: 6/29/11
Britta Bloomberg, Deputy State Historic Preservation Officer

Concur:

CITY OF FARGO

BY: ______________________ Date: 7-11-11
Dennis Walaker, Mayor

CITY OF MOORHEAD

BY: ______________________ Date: 7-6-2001
Mark Voxland, Mayor

BY: ______________________ Date: 7-6-11
Michael J. Redlinger, City Manager

CASS COUNTY BOARD OF COMMISSIONERS

BY: ______________________ Date: 7-6-11
Darrell Vanyo, Chairman

CLAY COUNTY BOARD OF COMMISSIONERS

BY: ______________________ Date: 7/6/11
Jon Evert, Chairman

Concur:

SISSETON WAHPETON OYATE

BY: ______________________________ Date: ________________
Robert Shepherd, Chairman

WHITE EARTH BAND OF MINNESOTA CHIPPEWA

BY: ______________________________ Date: ________________
Erma Vizenor, Chairwoman

LEECH LAKE BAND OF OJIBWE

BY: ______________________________ Date: ________________
Arthur "Archie" LaRose, Chairman

TURTLE MOUNTAIN BAND OF CHIPPEWA

BY: ______________________________ Date: ________________
Merle St. Claire, Chairman

UPPER SIOUX COMMUNITY OF MINNESOTA

BY: ______________________________ Date: ________________
Kevin Jensvold, Chairman

LOWER SIOUX INDIAN COMMUNITY

BY: ______________________________ Date: ________________
Gabe Prescott, President

Concur:

SPIRIT LAKE TRIBE

BY: ______________________________ Date: ________________
Roger Yankton, Sr., Chairman

BOIS FORTE BAND OF CHIPPEWA INDIANS

BY: ______________________________ Date: ________________
Kevin Leecy, Chairman

THREE AFFILIATED TRIBES (MANDAN, HIDATSA AND ARIKARA NATION)

BY: ______________________________ Date: ________________
Tex G. Hall, Chairman

NORTHERN CHEYENNE TRIBE

BY: ______________________________ Date: ________________
Leroy Spang, President

STANDING ROCK SIOUX TRIBE

BY: ______________________________ Date: ________________
Charles W. Murphy, Chairman

ASSINIBOINE AND SIOUX TRIBES OF THE FORT PECK INDIAN RESERVATION

BY: ______________________________ Date: ________________
A.T. "Rusty" Stafne, Chairman

Concur:

YANKTON SIOUX TRIBE

BY: ______________________________ Date: ____________________

Robert Cournoyer, Chairman

CROW CREEK SIOUX TRIBE

BY: ______________________________ Date: ____________________

Duane Big Eagle, Sr., Chairman

FLANDREAU SANTEE SIOUX TRIBE

BY: ______________________________ Date: ____________________

Anthony Reider, President

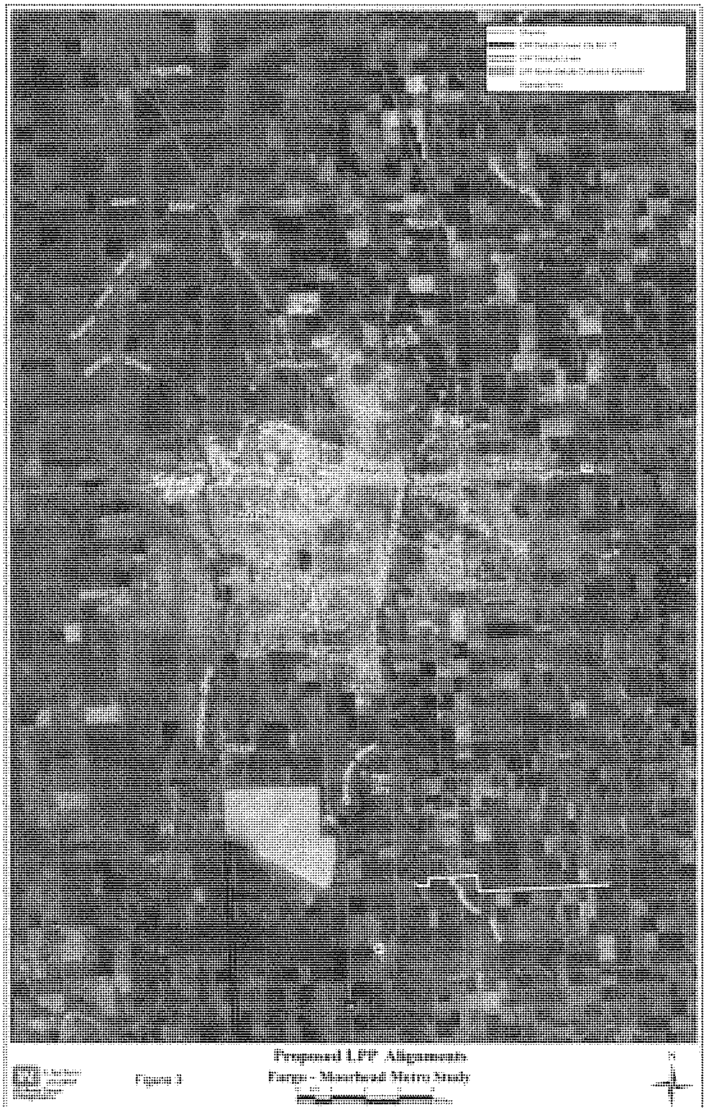

Figure 1. Proposed North Dakota Diversion alignments (Locally-Preferred Plan).

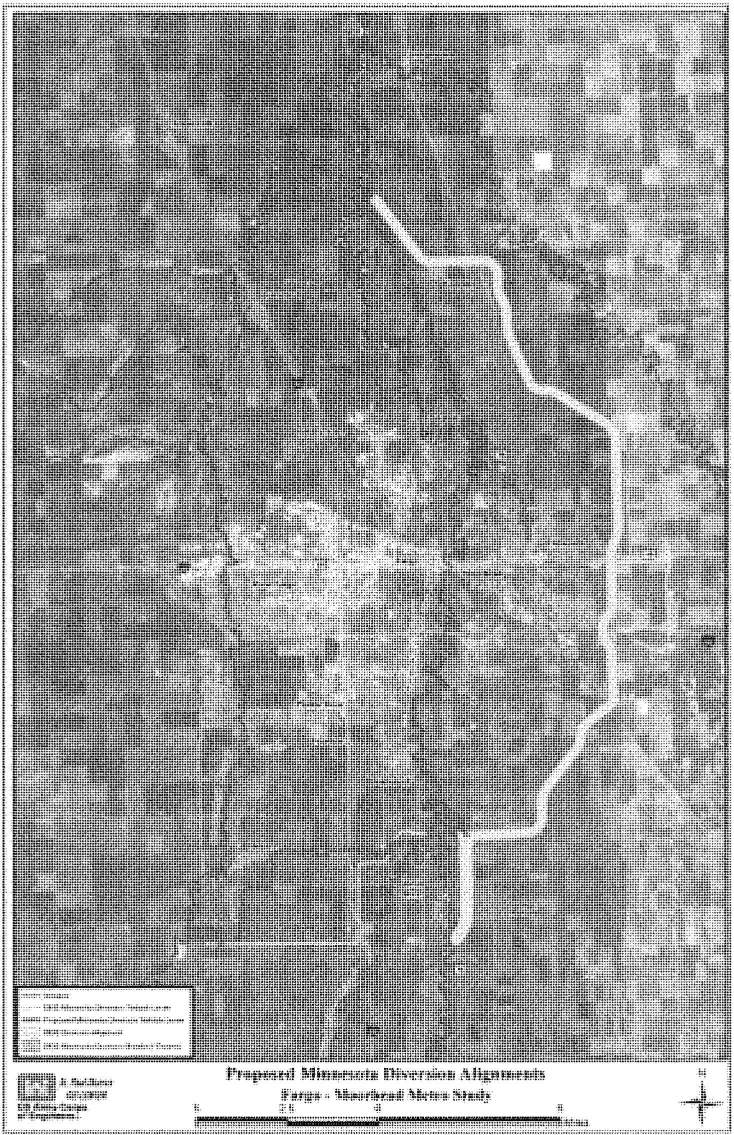

Figure 2. Proposed Minnesota Diversion alignments (Federally Comparable Plan).

Attachment 4

Fargo-Moorhead Metro

Final Feasibility Report and Environmental Impact Statement

July 2011

Mailing List

STATE/AGENCY RELEASE OF FEIS - JULY 2011							
	Number of Copies						
EIS Contact Info. Fargo-Moorhead Project	Hardcopy of Entire SDEIS Corps Report, Attachments, and Appendices.	Hardcopy of Corps Main SDEIS Report Only (report & attachments)	CD of Corps report, attachments, & appendices	CD of AE report	Hardcopy of Entire AE report	project summary (with DVDs)	Cultural appendix
FEDERAL AGENCIES							
Advisory Council on Historic Preservation							
Mr. John M. Fowler Executive Director Advisory Council on Historic Preservation 1100 Pennsylvania Avenue NW, Suite 803 Washington, DC 20004 Phone: 202.606.8503		1	1	1			
Eastern Office of Project Review Advisory Council on Historic Preservation 1100 Pennsylvania Avenue NW, Suite 803 Washington, D.C. 20004		1	1	1			
Department of Agriculture							
State Director ND State Farm Service Agency Office 1025 28th Street South Fargo, ND 58103		1	1	1			
Regional Forester, Northern Region 1 USDA Forest Service Federal Building P.O. Box 7669 Missoula, MT 59807 Phone: 406.329.3315		1	1	1			
U.S. Forest Service Eastern Region-9 626 East Wisconsin Avenue Milwaukee, WI 53202 Phone: 414.297.3600 North Dakota		1	1	1			
State Conservationist , Paul Sweeny Natural Resources Conservation Service Federal Building 220 E. Rosser Ave. Room 270 Bismarck, ND 58502-1458 Phone: 701.530.2003 Minnesota		3	3	3			
State Conservationist, Don A. Baloun United States Department of Agriculture Natural Resources Conservation Service 375 Jackson Street, Suite 600 Saint Paul, Minnesota 55101 Phone: 651. 602.7900		3	3	3			
Steve Kokkinakis National Oceanic and Atmospheric Administration 1315 East West Highway (SSMC, PPI/SP) Sliver Spring, MD 20910		1	1	1			
Environmental Protection Agency							
USEPA, Office of Federal Activities EIS Filing Section Room 7220, Mail Code 2252A South Ariel Rios Building 1200 Pennsylvania Avenue, NW. Washington, DC 20460 **(EIS Filing)** **FOR COURIER SERVICE USE THE FOLLOWING:** USEPA, Office of Federal Activities EIS Filing Section Room 7220 (202) 564-2400 South Ariel Rios Building 1200 Pennsylvania Avenue, NW. Washington, DC 20460	1		4	4	1		
Chief, NEPA Unit USEPA, Region 8 (8EPR-N) 1595 Winkoop Street Denver, Colorado 80202-1129 Phone: 303.312.6870		1	1	1			

Attachment 4 - FEIS Mailing List

Ken Westlake (E-19J) NEPA Implementation Section USEPA Region 5 77 West Jackson Blvd. Chicago, IL 60604-3590 Phone: 800.621.8431		1	1	1			
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Federal Emergency Management Agency							
Federal Emergency Management Agency Federal Center Plaza Room 713 500 C Street, SW Washington, DC 20472 Phone: 202.646.2500		1	1	1			
Cathy Brock Federal Emergency Management Agency Region 8 Denver Federal Center Building 710, Box 25267 Denver, CO 80225-0267 Phone: 303.235.4800		2	2	2			
Federal Emergency Management Agency Region 5 536 South Clark Street 6th Floor Chicago, IL 60605 Phone: 312.408.5500		2	2	2			
Department of Interior							
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U.S. Geological Survey District Chief- Jim Stark 2280 Woodale Drive Mounds View, MN 55112 Phone: 763.783.3100		1	1	1			
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Bureau of Reclamation Dakota Areas Office PO Box 1017 Bismarck, ND 58502 Phone: 701.250.4242		1	1	1			
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Attachment 4 - FEIS Mailing List

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Regional Director, Region 4 Federal Railroad Administration 200 West Adams Street, Suite 310 Chicago, IL 60606 Phone: 312.353.6203		1	1	1			
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Honorable John Hoeven U.S. Senate G11 Dirksen Senate Office Bldg. Washington, DC 20510 Phone: 202.224.2551		1	1	1			
Honorable Al Franken U.S. Senate 320 Hart Senate Office Bldg. Washington, DC 20510 Phone: 202.224.5641		1	1	1			
Honorable Amy Klobuchar U.S. Senate 302 Hart Senate Office Bldg. Washington, DC 20510 Phone: 202.224.3244		1	1	1			
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Congressman Rick Berg U.S. House of Representatives 323 Cannon HOB Washington, DC 20515-3401		1	1	1			
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Attachment 4 - FEIS Mailing List

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Mr. Elgin Crows Breast Tribal Historic Preservation Officer Three Affiliated Tribes Mandan, Hidatsa and Arikara Nation 404 Frontage Raod New Town, ND 58763		1	1	1			1
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Ms. Waste'Win Young Tribal Historic Preservation Officer Standing Rock Sioux Tribe P.O. Box D Fort Yates, ND 58538		1	1	1			1
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Ms. Lana Gravatt Tribal Historic Preservation Officer Yankton Soiux Tribe P.O. Box 248 Marty, SD 57361		1	1	1			1
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Commissioner, Edward Ehlinger, MD MN Department of Health 625 Robert Street N. St. Paul, MN 55155-2538 Phone: 651.201.5810		1	1	1			
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Mr. Craig Affeldt Environmental Assesment Minnesota Pollution Control Agency 520 Lafayette Road St. Paul, MN 55155-4194 Phone: 651.296.6300		1	1	1			
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Mayor Chad Olson City of Dilworth 607 3rd St. NE Dilworth, MN 56529		1	1	1			
Chairman Brian Thomas Kragnes Township 2218 130 Ave. N. Moorhead, MN 56560		1	1	1			
Mayor Cecil Johnson City of Glyndon 36 3rd St. SE Glyndon, MN 56547		1	1	1			
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Doug Goehring, Agricultural Commissioner ND Department of Agricultural 600 E Boulevard Ave Dept 602 Bismarck, ND 58505-0020		1	1	1			
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David Glatt Chief of Environmental North Dakota Department of Health 918 East Divide Ave. Bismarck, ND 58501-1947 Phone: 701.328.2372		1	1	1			
Mr. Todd Sando North Dakota State Water Commission 900 East Boulevard Bismarck, ND 58505 Phone: 701.328.2750		1	1	1			
North Dakota State Water Commission North Dakota Red River Joint Water Resource District 900 East Boulevard Bismarck, ND 58505		1	1	1			
State Historic Preservation Officer State Historical Society of North Dakota North Dakota Heritage Center 612 East Boulevard Avenue Bismarck, ND 58505-0830 Phone: 701.328.2666		1	1	1			
Director, Greg Wills North Dakota Department of Homeland Security PO Box 5511 Bismarck, ND 58506-5511 Phone: 701.328.8100		1	1	1			
Director David Sprynczynatyk North Dakota Department of Emergency Services PO Box 5511 Bismarck, ND 58506-5511 Phone: 701.328.8100		1	1	1			
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Agriculture Commissioner, Doug Goehring North Dakota Department of Agriculture 600 East Boulevard Avenue Bismarck, ND 58505 Phone: 701.328.2231		1	1	1			
Director, Francis Ziegler North Dakota Department of Transportation 608 East Boulevard Avenue Bismarck, ND 58505-0020 Phone: 701.328.2500		1	1	1			
State Forester: Larry Kotchman North Dakota Forest Service Molber Forestry Center 307 First Street East Bottineau, ND 58318-1100 Phone: 701.228.5422		1	1	1			
Cass County, North Dakota P.O. Box 2806 Fargo, North Dakota 58108-2806		1	1	1			
Cass County Joint Water Resource District 1201 Main Ave. W. West Fargo, ND 58078-1301		1	1	1			
North Dakota Wildlife Federation ATTN: Charles Vasicek 1605 East Capitol Avenue Halkirk offices Suite #102 Bismarck, ND 58501-2102 Phone: 701.222.2557		1	1	1			

Fargo-Moorhead Metropolitan Council of Governments Case Plaza, Suite 232 One Second Street North Fargo, ND 58102-4807 Phone: 701.232.3242		1	1	1			
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Mayor Bill Rohrich City of Harwood PO Box 65 108 Main St. Harwood, ND 58042		1	1	1			
Mayor Shane Waloch City of Horace 215 Park Dr. E. Horace, ND 58047		1	1	1			
Mayor Jim Nyhof City of Oxbow 708 Riverbend Rd. Oxbow, ND 58047		1	1	1			
Mayor Mark Anderson City of Mapleton PO Box 94 Mapleton, ND 58059-0094		1	1	1			
Mayor Darren Wentzel City of Argusville 201 N Hwy 81 Argusville, ND 58005-4108		1	1	1			
Mayor Rich Mattern City of West Fargo 800 4th Ave. W. West Fargo, ND 58078		1	1	1			
Mayor Jefferson Bay City of Reiles Acres 4515 35th Ave. N. Reiles Acres, ND 58102-5413		1	1	1			
Mayor David Susag City of North River 5302 River Dr. Fargo, ND 58102-7002		1	1	1			
Mayor Penny Kianian City of Prairie Rose 3308 40th Ave. S. Fargo, ND 58104-6626		1	1	1			
Mayor Barry Wegner City of Frontier 5301 33rd St. S. Fargo, ND 58104-6775		1	1	1			
Mayor John Adams City of Briarwood 8 Briarwood Place Briarwood, ND 58104-7308		1	1	1			
Mayor Wayne Lunder City of Kindred 230 Sheyanne St Kindred, ND 58051-4329		1	1	1			
Chairman Steve Brakke Village of Hickson 5060 173rd Avenue SE Horace, ND 58047-9755		1	1	1			
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Mayor Steve Moen City of Colfax PO Box 66 Colfax, ND 58018		1	1	1			
Harris Bailey, Auditor Richland County Commissioners 418 2nd Ave. N Wahpeton, ND 58075-4400		1	1	1			

LIBRARIES							
Fargo Public Library 102 N. 3rd Street Fargo, ND 58102-4899	1		1	1			
Annette Graves Administration/ HR Assistant Lake Aggasiz regional Library Distribute to: Moorhead Public Library 118 South 5th Street Moorhead, MN 56560-0076	1		1	1			
West Fargo Public Library 401 7th St. E West Fargo, ND 58078-2809	1		1	1			
Fargo Public Library, Carlson Branch 2801 32 Ave. South Fargo, ND 58103	1		1	1			
Annette Graves Administration/ HR Assistant Lake Aggasiz regional Library distribute to: Climax 118 South 5th Street Moorhead, MN 56560-0076	1		1	1			
Annette Graves Administration/ HR Assistant Lake Aggasiz regional Library Distribute to: Breckenridge 118 South 5th Street Moorhead, MN 56560-0076	1		1	1			
Kindred Public Library 330 Elm Street Kindred, ND 58051	1		1	1			
OTHERS							
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Mr. Girma Sahlu Environment Canada Park Plaza, Room 300 2365 Albert Street Regina, Saskatchewan S4P 4K1		1	1	1			
International Red River Board Secretary, Scott Jutila 190 East Fifth Street St. Paul, MN 55101-1667		2	2	2			
Red River Basin Commission 206-309 Hargrave Street. Winnipeg, MB R3B 2J8 Phone: 204.982.7255		1	1	1			
Red River Basin Commission 119 South Fifth Street P.O. Box 66 Moorhead, MN 56560 Phone: 218.291.0422		1	1	1			
Red River Watershed Management Board P.O. Box 763 Detroit Lakes, MN 56502-0763 Phone: 218.844.6166		1	1	1			

Attachment 4 - FEIS Mailing List

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Ms. Helen Nygren 1000 W Captial Ave Bismarck, ND 58501		1	1	1			
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City of Moorhead	1		1	1	1		
Cass County	1		1	1			
Clay County	1		1	1			
St Paul district	1	21	225	225	1		

Attachment 5

Fargo-Moorhead Metro

Final Feasibility Report and Environmental Impact Statement

July 2011

Consultant's Report

(The contents of this report have not changed from the SDEIS dated April 2011)

Attachment 6

Fargo-Moorhead Metro

Final Feasibility Report and Environmental Impact Statement

July 2011

DISCUSSION OF HABITAT LOSS, MITIGATION NEEDS AND ADAPTIVE MANAGEMENT

ATTACHMENT 6

DISCUSSION OF HABITAT LOSS, MITIGATION NEEDS AND ADAPTIVE MANAGEMENT FINAL ENVIRONMENTAL IMPACT STATEMENT

1. Overview

Considerable efforts have been made with an interagency team to avoid and minimize project impacts by modifying alternative designs. However, the diversion channel alternatives would still result in the impacts identified in the main report for aquatic habitat, riparian forest and wetland resources. For these impacts, mitigation will be implemented to offset these adverse effects to the greatest extent practicable.

Corps regulations (ER 1105-2-100) require assessment of environmental impacts and associated mitigation actions in a manner that addresses changes in ecological resource quality. Changes to habitat must be assessed as a function of improvement or degradation in habitat quality and/or quantity, as expressed quantitatively in physical units or indexes (but not monetary units). In the case of mitigation for significant environmental impacts, ecosystem restoration actions must be formulated and evaluated in terms of their net contributions to increases in ecosystem value, expressed in non-monetary units. Mitigation actions also need to go through a Cost Effectiveness and Incremental Cost Analysis (CE/ICA) to ensure benefits are optimized relative to cost.

Corps regulations also require projects take an adaptive approach to implementing, monitoring and modifying mitigation actions to ensure they are offsetting significant project impacts (USACE Implementation Guidance for Section 2036a of WRDA 2007, Aug 2009). This guidance requires mitigation plans include: 1) monitoring until successful; 2) criteria for determining ecological success; 3) description of available lands and the basis for the determination of availability; 4) development of contingency plans (i.e., adaptive management); 5) identification of the entity responsible for monitoring; and 6) establishing a consultation process with appropriate federal and State agencies in determining the success of mitigation.

This attachment provides a detailed discussion on habitat impacts quantification, mitigation and adaptive implementation, all of which are intended to ensure adverse effects from the project are offset.

Section 2 provides a habitat-based assessment of impacts for aquatic habitat, connectivity, forest and wetland resources. It assesses losses of habitat, due to the division channel alternatives, over the next 50 years.

Section 3 provides the basis for mitigation planning. It describes various alternatives for mitigating habitat losses, and compares the costs and benefits of these basic alternatives. Specific mitigation sites have not been finalized, given that final design of the project has not been determined. For this analysis, benefits of mitigation measures are based on their potential resulting habitat conditions. A CE/ICA was performed with these various alternatives to determine which provided the best option for mitigation. The amount of mitigation needed to offset project impacts is identified, and costs for implementing this mitigation is estimated. It should be noted that the Corps has and continues to coordinate with local agencies to refine mitigation plans. The Corps has identified several mitigation projects, and will continue to refine specific mitigation plans during detailed project design.

Section 4 outlines the adaptive process where project impacts will be verified, along with the effectiveness of project mitigation, through pre- and post- construction monitoring. It identifies the entities involved with collaboration, monitoring and data review. It also overviews a contingency process where corrective actions could be pursued should impacts prove greater than anticipated; and/or if mitigation is proves less effective at offsetting impacts.

Section 5 outlines specific monitoring activities that will be done pre- and post-construction, including cost estimates for these activities.

Section 6 outlines performance standards/metrics that will be used to measure the success of mitigation. Collectively, this attachment will drive data collection and review. Monitoring results will be compared in the future to verify whether the impacts of the project have been offset by mitigation actions. It should be noted that many of these details are currently being refined, and will be finalized prior to construction. In addition, this Adaptive Management Plan will need to remain flexible to adapt to the needs of the project over time. As such, this document is open to change throughout the life of the project. However, this forms the basis for confirming project impacts, and whether these impacts have been offset with mitigation.

2. ASSESSMENT OF IMPACTS AND HABITAT LOSS

The following discussion outlines how impacts are quantified in terms of habitat value. Habitat impacts will be further evaluated with detailed field assessments prior to any construction activities. The assessment here is provided based on the best existing information.

2.1 Project Impacts: Aquatic Habitat Footprint

Project impacts were first identified by reviewing features of the diversion channel alternatives and quantifying the amount of aquatic habitat impacted. To quantify footprint areas, aerial photos were reviewed within GIS to estimate the amount of riverine habitat directly affected by individual project features. The upstream and downstream extent of the footprint were first identified based on likely feature boundaries. The channel area was then identified laterally up the bank to approximately a bankfull elevation, typically identified by the presence of trees. A polygon was then established to quantify the amount of aquatic habitat impacted. These footprint areas are outlined in the main report.

The quality of these areas impacted was then quantified by using Index of Biotic Integrity (IBI) scores from EPA (1998). IBI scores from EPA (1998) were used in a fashion similar to those employed under the USFWS Habitat Evaluation Procedures (HEP). The approach here utilized the IBI scores as a qualitative description of habitat quality, scoring habitat conditions on a scale of 0.1 to 1.0 based on EPA (1998) IBI observations for the Red River Basin. IBI scores provide insight into biotic community structure, and thus aquatic health and habitat quality in stream areas. From field observations, EPA (1998) calculated quantitative scores, which were converted into the following integrity classes: Excellent, Good, Fair, Poor, and Very Poor. To apply the IBI as a quality factor, each of the classes was assigned a quantitative value between 0.1 and 1.0 (Table 1). To assess habitat quality in footprint impact areas, the closest IBI observation was used for each aquatic area (Figure 1). The applied quantitative score was multiplied by the acres impacted by the footprint to derive a total number of Habitat Units lost.

From the qualitative and quantitative determinations, the standard unit of measure, the Habitat Unit (HU), is calculated using the formula: IBI score x Acres = HUs. While this not a formal HEP model, this approach does provide a method to assess habitat loss with available information. This approach suggests that, for the FCP, about 27-28 acres of footprint impact to aquatic habitat results in about 15.1 Habitat Units lost (Table 2). Conversely, for the ND35K and LPP, about 45.4 acres of footprint impact to aquatic habitat results in about 16.9 Habitat Units lost (Table 3).

For the purpose of this assessment, it is assumed that habitat within the footprint will be completely lost, with mitigation to create or improve habitat nearby. In reality, some habitat would exist within the newly excavated channels leading into and out of project structures. These newly excavated areas will be evaluated during post-project monitoring to determine what habitat they provide. However, to be conservative with our impact assessment and mitigation estimates, it is assumed that existing river channel substantially modified or abandoned under the project will be permanently lost.

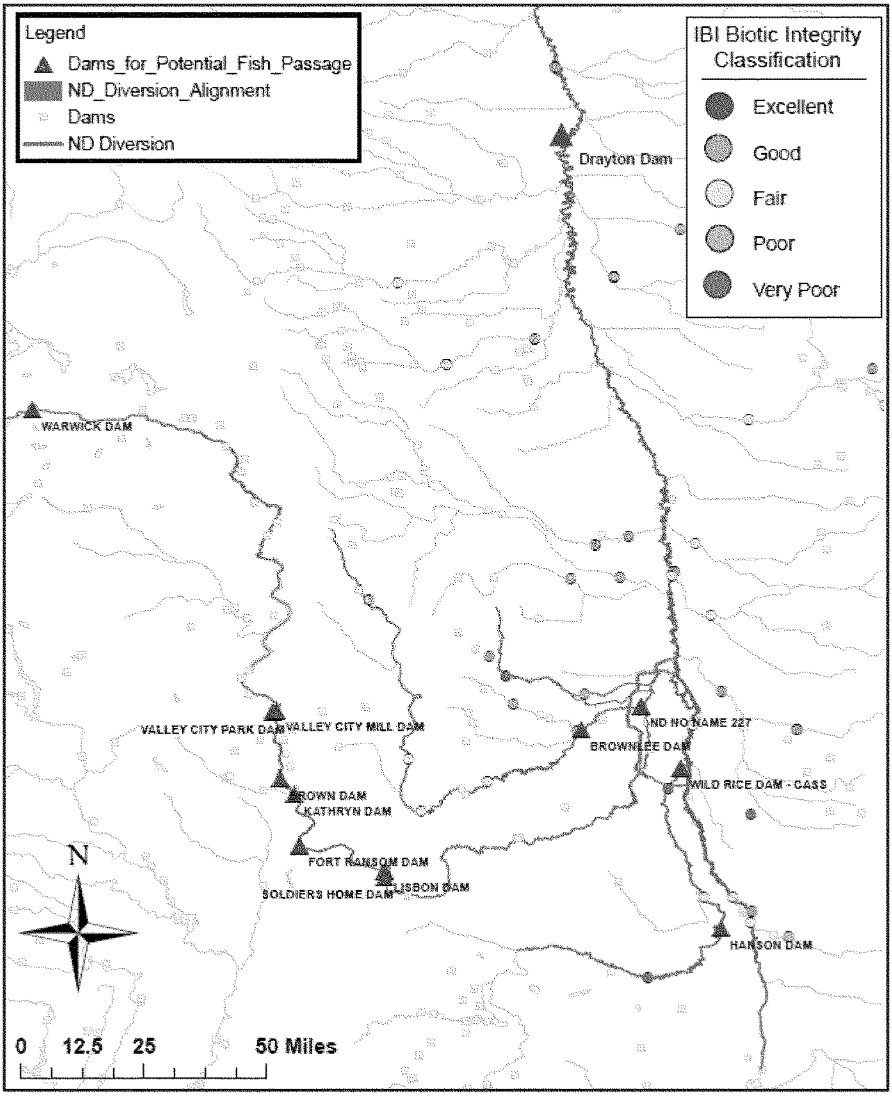


Figure 1. Index of Biotic Integrity observations (EPA 1998) for various tributaries in the Red River Basin. Dams considered for potential fish passage, as a mitigation approach, are also noted.

Table 1 Quantitative score assumed for each IBI integrity class from EPA (1998).

IBI Integrity Class (EPA 1998)	Applied Quantitative Score
Excellent	1.0
Good	0.8
Fair	0.55
Poor	0.3
Very Poor	0.1

Table 2 Footprint impact areas and corresponding habitat units for aquatic impacts by project features under the FCP.

Impact	Footprint Impact Area (ac)	IBI Integrity in Footprint Area*	Habitat Units
Red River Control Structure	27.5	0.55	15.1
Red River Outlet Structure	0**	0.55	0
Total	27.5		15.1

* IBI score based on the closest IBI observation to the impact area on the same stream.
** The outlet structure will have rock erosion protection that occurs within aquatic habitat. This footprint is not included here as it was determined to not be a significant loss or degradation to habitat that would require additional mitigation.

Table 3 Footprint impact areas and corresponding habitat units for aquatic impacts by project features under the ND35K and LPP alternatives.

Impact	Footprint Impact Area (ac)	IBI Integrity in Footprint Area*	Habitat Units
Red River Control Structure	13.9	0.55	7.6
Red River Outlet Structure	0**	0.55	0
Wild Rice River Control Structure	12.1	0.1	1.2
Sheyenne River Aquaduct	8.4	0.55	4.6
Maple River Aquaduct	10.7	0.3	3.2
Wolverton Creek Tie-back Levee	0.3	0.8	0.2
Total	45.4		16.9

* IBI score based on the closest IBI observation to the impact area on the same stream. No IBI observations were provided for Wolverton Creek. To be conservative, the IBI was assumed at 0.8 ("good" integrity), which is the highest score for any stream in the project area (e.g., sections of the Red River; Buffalo River (MN) and Goose River (ND)).
** The outlet structure will have rock erosion protection that occurs within aquatic habitat. This footprint is not included here as it was determined to not be a significant loss or degradation to habitat that would require additional mitigation.

One final aspect to assessing lost habitat is how conditions could change over time. Changes in the amount of habitat (and habitat units) could occur as habitat changes and is influenced over time by river and watershed conditions. Improved watershed conditions could improve stream health in the future, thus habitat loss could be greater over time. Conversely, continued degradation could further reduce the amount of habitat that is lost through these footprint impacts. To help identify general habitat changes over time, Habitat Units are averaged over the life of the project (50 years) to determine what is known as the Average Annual Habitat Units (AAHUs). AAHUs are used to estimate site-specific changes for the diversion channel alternatives.

There is great uncertainty with how future habitat conditions will ultimately change in the project area. Continued urbanization in combination with existing land use practices will further stress aquatic ecosystems, which could result in further degradation. Conversely, efforts are ongoing in some watershed locations to improve at least some aspects of land use, habitat connectivity and site-specific habitat conditions.

Given the uncertainty with whether habitat conditions might generally improve or degrade, or to what magnitude such changes would occur, it is assumed that conditions would remain constant over time. It is recognized that habitat conditions likely will not remain constant. However, this approach hopefully minimizes the potential to either underestimate or overestimate potential project impacts.

The impacts outlined would occur immediately when project features are constructed, and remain constant over the project life. This assumption results in a total of 16.3 and 16.9 AAHUs lost through footprint impacts, respectively, for the Minnesota (FCP) and North Dakota diversion channel alternatives (LPP and ND35K).

2.2 Fish passage and Connectivity

The FCP and ND35K already include two fish passage channels to minimize adverse effects to connectivity. It is unlikely these two alternatives would have substantial impacts to long-term fish population trends due to reduced connectivity associated with these alternatives. No further mitigation is proposed for connectivity impacts under these two alternatives.

As with the FCP and ND35K, the LPP already includes two fish passage channels within the design presented here. However, the LPP results in upstream staging of water, and two fish passage channels would only provide narrow windows during operation when fish passage could be provided. Installation of additional fish passage channels at the Red River control structure would help alleviate this problem. In addition, the LPP could potentially impact connectivity through a protracted period of operation, relative to the FCP and ND35K. , Additional mitigation could be warranted to address this issue. The frequency and timing of project operations, and thus the effects to connectivity, are outlined in the main report. This reduction in connectivity would reduce access to over 400 miles of river habitat (estimated at roughly 3,700 acres of aquatic habitat). Although observations are limited, this included areas observed by EPA (1998) as "fair" in terms of biotic integrity. Following the approach outlined above, this would equate to over 2,000 AAHUs that could be less available under the LPP. Given the concern with connectivity expressed by the natural resource agencies for the Red River, additional mitigation would be implemented to offset this impact.

Similarly, the LPP also could potentially impact connectivity on the Wild Rice River. The level of impact could be slightly different from that on the Red River, given limited connectivity and habitat integrity on the Wild Rice. The presence of two low-head dams already fragments connectivity on the Wild Rice (Figure 1), with a dam both upstream and downstream of the proposed structure. It should be noted that these two low-head dams likely are an impediment during low-flow periods, while the proposed Wild Rice structure would be an impediment during high-flow periods. Habitat value within the Wild Rice appears limited, with IBI scores observed by EPA (1998) that ranged from "fair" to "very poor". When operating, the project could reduce access to approximately 350 AAHUs of available Wild Rice River habitat (based on access to 1,400 acres of habitat, with a quality of 0.25). Given the expense of installing additional fish passage channels and the presence of other barriers to connectivity, it is possible that greater benefits could be obtained by implementing additional mitigation for connectivity impacts elsewhere on the Wild Rice River rather than installing additional fish passage features at the structure.

The LPP and ND35K could disrupt fish migrations by attracting fish into the diversion channel that would be unable to migrate through the upstream end of the diversion. The impact would likely be more pronounced under the LPP which would operate for a longer period of time. However, this impact is speculative, and difficult to assess prior to project operations. Moreover, fish would be able to migrate out of the diversion and back to the Red River. No mitigation is currently budgeted for resolving this impact. However, should the impact be found to be significant within the first few years of operation, construction funds could be used to consider and implement potential mitigation. Contingency funding for mitigation would likely cover this expense, depending on what solutions are identified.

The LPP could disrupt fish migrations through Wolverton Creek due to the presence of a gate necessary to control upstream water elevations during staging. However, it is unknown how the upper reaches of Wolverton Creek are used by fisheries resources. Moreover, fish passage at this feature would likely be expensive to mitigate. No mitigation is currently budgeted for this impact. However, this impact will be evaluated through monitoring, and additional mitigation could be pursued in the future if any substantial impacts are identified.

2.3 Other Aquatic Impact Conclusions

No other mitigation is currently proposed for aquatic impacts.

As discussed in the main report, project features for the FCP, ND35K, and LPP would not be expected to result in significant adverse impacts to aquatic habitat via altered geomorphic conditions.

The LPP could have the potential to result in fish stranding in upstream areas where water staging occurs. However, this impact is largely unknown and will require project operation and monitoring to fully gage whether there are any substantial impacts. Any impacts would require further evaluation before mitigation would be pursued.

2.4 Project Impacts: Floodplain Forest

Construction of the three diversion channel alternatives for the Fargo Moorhead Metro Flood Risk Reduction Project would result in the loss of floodplain forest and upland forest. An estimated 117 acres of floodplain forest would be affected by both the ND35K and the LPP, and 42 acres of floodplain forest would be affected by the FCP. An additional 41.5 acres of upland forest will be lost for the ND35K, 82 acres for the LPP and 47 acres for the FCP. The upland forested acres mostly consist of shelter belts or small pockets of forest around farmsteads.

The U.S. Fish and Wildlife Service's 1980 version of its Habitat Evaluation Procedures (HEP-80) was used to quantify and evaluate the potential project impacts on floodplain forests and to evaluate mitigation approaches. The HEP methodology utilizes a Habitat Suitability Index (HSI) to rate habitat quality on a scale of 0 to 1 (1 being optimum – see Table 4). The HSI is multiplied by the number of acres of available habitat to obtain Habitat Units (HU's). One HU is defined as one acre of optimum habitat. By comparing existing HU's with expected HU's lost or gained with an alternative, impacts can be quantified.

Table 4 Habitat Suitability index rankings

Habitat Suitability Index	Verbal Equivalent
0.0 < 0.2	Poor
0.2 < 0.4	Marginal
0.4 < 0.6	Fair
0.6< 0.9	Good
0.9 < 1.0	Optimum

HEP Model Selection

Given the nature and types of impacts expected with the diversion channel alternatives, a riparian community model that addresses composition, structure, diversity and extent in the landscape would be most appropriate for the analysis of floodplain forest impacts. While there are several riparian/woodland community models that have been certified, there are no certified HSI community models available that would be applicable to the project area. Therefore, several existing species models were used to identify the range of effects on different components of the riparian community.

Through interagency coordination five species were selected in order to evaluate the area that would be impacted: the Belted Kingfisher (*Megaceryle alcyon)*, Gray Squirrel (*Sciurus griseus)*, Wood duck (*Aix sponsa)*, Black-capped Chickadee (*Poecile atricapillus*), and Mink (*Mustela vison)*. Each one of these species requires habitat that is included in a riparian area. The kingfisher model and gray squirrel model were selected based on recommendations from the North Dakota Game and Fish (NDGF), because king fisher's are typically a bird of riparian habitat and the gray squirrel model measures the value of forest diversity. The wood duck model measures the availability of snags or cavity trees which are important for nesting, the black-capped chickadee looks at forest composition and the mink model measures vegetative cover near, in, and over the rivers. HSI values were calculated for the five species using field data collected in the floodplain forest along the Red River, Sheyenne River and Wild Rice River.

Data Requirements

Table 5 lists the model variables identified in each of the five species models, the method used for collecting the field data, and the HSI equation used for the analysis.

Table 5. Variables for each HEP model.

Belted Kingfisher	Variable	Variable Description
Measured	V2	Water Transparency
Measured	V3	% cover of emergent vegetation
Measured	V4	% of water deeper than 24 inches
Measured	V5	% riffles
Estimated	V6	Average shoreline subsection with perches
Estimated	V7	Distance to nearest suitable soil bank
HSI Equation		(SIV2 X SIV4 X SiV5)^1/3 X SIV3
Gray Squirrel	Variable	Variable Description
Measured	V1	% hard mast producing trees
Count	V2	# of hard mast producing trees
Measured	V3	% canopy cover
Measured	V4	% canopy cover
Measured	V5	Mean DBH of overstory
		(SIV1 X SIV2)^1/2 X SIV3 = SIWF
		(SIV4 X SIV5)^1/2 = SICR
Wood duck	Variable	Variable Description
Counted	V1	# of suitable cavities/acre
Counted	V2	# of nest boxes 0
Totaled	V3	total of V1 plus V2 (.18 X V1) + (.95 X V2)
measured	V4	% of water surface covered
Black-capped chickadee	Variable	Variable Description
measured	V1	% canopy cover
measured	V2	Average height of overstory
measured	V4	# of snags/acre
		(V1 X V2)^.5 = Food Life Requisite
		V4 = Reproduction Life Requisite
Mink	Variable	Variable Description
measured	V1	% tree/shrub canopy cover
measured	V2	% of year with surface water present
measured	V4	% cover trees/shrubs within 100m of water
		(V2^2 x V4)^.3333 = River Life requisite

The Corps of Engineers and the North Dakota Fish and Game Department collected baseline data in the riparian forests that would be potentially impacted by the diversion channel alternatives. This included the areas affected by the construction of the diversion control structure on the Red River, the construction of aqueducts on the Wild Rice and Sheyenne rivers, and areas that would be impacted by the proposed diversion channel construction for the FCP, the ND35K, and the LPP. The ND35K and LPP would also impact minimal forested land on the Maple River, but access was not granted at the time of the data collection. Forested land near the potentially affected area was observed and it was determined that the forested land was similar to lands that were surveyed on the Wild Rice River and Sheyenne River.

Data collection included transects through the forest stands, secchi readings, canopy closure measurements, tree measurements, basal area measurements, nest trees counts, and stream observations for woody debris. The data was collected using measurement techniques and protocols described in the HEP models or ocular estimations when direct measurements could not be taken. This data was compared to efforts previously completed in the region by Houston Engineering, for which they collected tree composition data on forested stands along the Red River. The analysis completed for this effort and the effort conducted by Houston Engineering showed consistent results. Maps, data sheets, and summaries of each stand inventory can be found in Appendix F.

Analysis

In the absence of a community model, and recognizing that quantified impacts and subsequent mitigation needs can be driven by the model that is selected, the HSI scores for the five species were averaged. This approach may slightly understate or overstate the potential impacts as the average often drifts towards the middle (i.e. HSI = .5) and limits the sensitivity of the analysis for subtle changes in habitat conditions. However, it does provide better insight on the overall forest community. As a sensitivity analysis, the range in impacts and potential mitigation needs were calculated for each of the species modeled.

Assumptions

The following assumptions were used for conducting the HEP analysis:

1. The habitat conditions along the Red River and the tributaries will remain essentially unchanged for the 50 year analysis period. While there may be some slight changes in acreage, the species composition and structure of the remaining woodlands is not expected to change dramatically.
2. The construction disturbance footprint of the diversion channel alternatives is mostly in bottomland hardwoods. While there would be other forested areas impacted with project construction, these areas are shelterbelt plantings and have been included in the total acreage of floodplain forest.
3. Any compensatory mitigation would involve the restoration of existing floodplain agricultural land to floodplain forest.
4. It would take 50 years for mature bottomland hardwood habitat to develop.
5. Floodplain agricultural land provides some limited habitat value.
6. Establishment of floodplain forest on floodplain agricultural lands would be an acceptable approach for mitigating for unavoidable impacts associated with forest impacts.
7. The period of analysis is 50 years.

Existing Conditions: Existing riparian habitat conditions in the project area are generally considered to be fair with an average HSI for the five species of .51. Habitat conditions for the individual species range from poor (HSI=.17 for the wood duck and gray squirrel) to near optimum (HSI = .98 the mink).

Future Without Project Conditions: As noted above, woodland extent, structure and composition is assumed to remain fairly similar to existing condition. While habitat value for individual species may change over time as natural setback/succession processes occur on these established tracts, the overall habitat value for the riparian woodland community would remain essentially the same and be rated as fair with an HSI of .51.

Future With Project: Construction of the features of the ND35K alternative would potentially result in the loss of 159 acres of woodlands (30 acres along the Red River, 20 acres along the Wild Rice River, 10 acres along the Sheyenne River, 3 acres along the Maple River and 97 acres along the diversion channel route). Based on the existing HSI, this would result in the loss of 82 Average Annual Habitat Units (AAHU's). The FCP would potentially result in the loss of 89 acres of woodlands (42 acres along the Red River and 47 acres along the diversion channel route). Based on the existing HSI, this would result in the loss of 46 AAHU's. The LPP would potentially result in the loss of 199 acres of woodlands (30 acres along the Red River, 20 acres along the Wild Rice River, 10 acres along the Sheyenne, 3 acres along the Maple River, 97 acres along the diversion channel route, and 40 acres within the storage area). Based on the existing HSI, this would result in the loss of 103 AAHU's.

2.5 Project Impacts: Wetland Habitat Footprint

As part of the assessment of impacts to aquatic resources and based on recommendations from the interagency team, the Minnesota Routine Assessment Methodology for Evaluating Wetland Functions (MnRAM Version 3.3) was used to assess the functions of wetlands within the diversion channel corridors. Due to the similarity of the identified wetlands, functionality was not assessed on every area determined to be wetland. Instead, at least one randomly-chosen area representative of each type of wetland found within the diversion channel alignments was assessed for typical functionality. The types of wetlands found within the diversion channel corridors, in accordance with Eggers & Reed are farmed seasonally flooded basin (PEMAf is the corresponding Cowardin classification), fresh wet meadow (PEMB), shallow marsh (PEMC), floodplain forest (PFO1A) and shallow open water (PUBH). Floodplain forest wetlands were assessed separately in Section 2.3 Project Impacts: Floodplain Forest and will not be analyzed further in this section except for brief description of functions. Table 6 below provides a breakdown, by type, of the total acreage of non-forested wetlands found in the project area.

European settlement of the project area involved extensive drainage in order to make production of agricultural crops possible, and much of the land within the proposed diversion channel alignments is currently used for agricultural purposes. Although the surface drainage systems (ditches) make agricultural production possible in many areas in most years, the ditches have not effectively removed wetland hydrology from the surface. These wetlands are farmed year after year, although crops are often lost in the areas with shallow depressions. Wetlands in this area have been significantly impacted by the agricultural practices, including the drainage of the natural hydrology, plowing of the soils and loss of the natural vegetation. The shallow marsh and floodplain forest areas, although usually left untouched by direct planting, have been affected by the agricultural runoff containing eroded soils and agricultural chemicals.

Table 6 Acres of wetland impact, by wetland type, for the FCP, ND35K, and LPP alternatives. Acres rounded up to the nearest whole acres, and do not include forested wetlands or in-stream acreage, which are addressed separately.

Wetland Type	North Dakota/LPP Corridor (Total area: 8054 ac)	North Dakota/ND35K Corridor (Total area: 6560 ac)	Minnesota/FCP Corridor (Total area: 6415 ac)
Approximate total acres hydric soil	7250	5900	4040
Farmed, seasonally flooded basin	790	720	800
Wet meadow	140	120	50
Shallow marsh	50	40	50
Shallow open water	10	10	10
Total Wetland Acreage	990	890	910

% Wetland	12%	14%	14%

Farmed seasonally flooded

As expected, wetlands found within those active agricultural lands provide limited levels of functionality due to the extensive drainage and overall alteration that has taken place in the region. Over seventy five percent of wetlands within the review area for the ND35K plan and over eighty percent of wetlands within the review area for the FCP are depressional field ditches and depressional isolated wetlands of the seasonally flooded basin type (see Picture 1). Due to the extensive drainage systems, these seasonally flooded wetlands generally function at a low level for *Maintenance of Hydrologic Regime* and *Maintenance of Wetland Water Quality*. When drainage moves water off the landscape more quickly than in a natural setting, wetlands do not have the opportunity to continually feed the downstream system with a supply of water, and the agricultural impacts directly affect the ability of the wetlands to maintain water quality within the basin. Because the wetlands are found within agricultural fields, they also function at a low level for *Maintenance of Character of Wildlife Habitat*, and *Aesthetics/Recreation/Education/Cultural benefit*. Without natural vegetation, there is no opportunity to provide wildlife habitat and the wetlands do not provide any aesthetic or recreational value to the human landscape.

The depressional wetland within agricultural fields do, however, generally provide moderate to high functionality for *Flood/Storm-water Attenuation* and *Downstream Water Quality*. Those wetlands that have been shaped into shallow field ditches provide a moderate level of flood/storm water attenuation because they are able to hold some of the water on the landscape for at least a short period of time. Shallow isolated depressional wetlands provide a high level of functionality for flood/storm water attenuation, as they are able to hold the water on the landscape until it can evaporate or infiltrate, rather than run off to nearby over-stressed water courses. All field wetlands provide a moderate level of functionality for protection of downstream water quality because they are able to filter at least some of the nutrients from the agricultural runoff before the water enters nearby waterways. The depressional wetlands generally do not provide any level of function for amphibian or fish habitat or shoreline protection, therefore functional analysis was not applicable in these areas.

Picture 1 Wetland in wheat field, (Farmed seasonally flooded)

Fresh Wet Meadow and Shallow Marsh

Fresh wet meadows and shallow marsh (Picture 2) wetlands that are not actively farmed within the diversion corridors provide similar levels of functionality as those described above for farmed seasonally flooded wetlands, with a few noted differences. For *Maintenance of Wetland Water Quality*, wet meadows and shallow marshes provide a moderate level of functionality. With natural vegetation present, such as cattails (*Typha sp.*), the water quality within the wetland is treated through the plants' uptake of nutrients. These wetlands also provide a moderate level of wildlife habitat because of the natural vegetation.

Picture 2Shallow Marsh along project corridor.

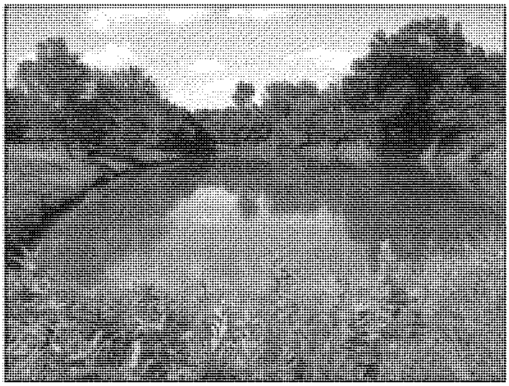
Floodplain Forest

Floodplain forest wetlands (Picture 3) provide a moderate level of functionality for maintenance of the hydrologic regime, as they are able to gradually feed the river system with water stored in the soils following flood events. In addition, the forest canopy provides the wetland with the opportunity to provide a moderate level of function for wildlife habitat. The floodplain forest wetland will not be discussed further in this section because they will be mitigated for as floodplain forests, which were discussed in section 2.3. Floodplain forest restoration is targeted for stream riparian areas. Thus, this mitigation also would include floodplain forest wetlands.

Picture 3 Floodplain Forest

Shallow Open Water

In the North Dakota diversion channel corridor, there are two areas classified as shallow open water (Picture 4). One is a constructed storm water retention pond at west edge of Prairie Rose, and the other is located adjacent to the Wild Rice River and is surrounded by a forested floodplain on private property. The storm water retention pond functions at a high level for flood and stormwater attenuation as well as protection of downstream water quality, and it functions at a low to moderate level for most other functions, such as amphibian and wildlife habitat and maintenance of hydrologic regime. The shallow open water basin adjacent to the Wild Rice River performs at a low to moderate level for all measured functions. While it can provide a moderate level of flood/stormwater attenuation and water quality protection, its outlet to the Wild Rice River is too low and not constricted, minimizing its ability to retain water. This basin provides a moderate level of wildlife and fish habitat, providing protection for water fowl and spawning habitat for fish.



Picture 4 Shallow Open Water near Wild Rice River

3. Assessment of Mitigation Alternatives

The discussion below outlines the assessment of possible mitigation measures for offsetting habitat losses identified above. The measures outlined below would be expected to mitigate project impacts and provide a basis for estimating costs. However, it should be recognized these mitigation features could be modified should new information warrant refining mitigation measures or locations. Implementation of mitigation features may include subsequent NEPA documentation, if warranted.

3.1 Aquatic Habitat Mitigation

Footprint Impacts

Measures considered for aquatic habitat mitigation include performing full stream restoration, stream improvement via riparian corridor restoration, and construction of fish passage.

Stream and riparian corridor restoration are direct, site-specific tools that offsets project impacts by restoring a specific amount of habitat to replace a specific amount of habitat lost or impaired. It could be the best mitigation option in terms of measuring specific habitat replacement, and monitoring to evaluate success of the mitigation.

Conversely, fish passage provides benefits to the aquatic community by restoring migratory pathways that are otherwise limited. Benefits can be significant and substantial. However, it can be more difficult to identify exactly how many fish passage projects are needed to offset footprint impacts. It also may be more difficult to evaluate whether the mitigation is completely offsetting the identified impact, although monitoring how well fish can navigate through a fish passage structure is possible.

Lengthy coordination with the State and federal natural resource agencies identified differences of opinion in the preferred methods for mitigation. Minnesota Department of Natural Resources (DNR) stated that site-specific mitigation was needed to offset habitat losses and measure success. North Dakota Game and Fish (NDGF) identified that fish passage was generally preferred for offsetting the aquatic impacts identified above. NDGF would support an approach that used both site-specific habitat restoration and fish passage for mitigation. Though stream restoration could provide definite, and more easily quantifiable aquatic habitat benefits, NDGF had significant concern whether an adequate number of sites could be identified for stream restoration. The USFWS stated that an approach that used multiple mitigation techniques (i.e., habitat restoration and fish passage) could be a reasonable approach to offsetting identified impacts.

The two stream mitigation alternatives include: full stream restoration (to include steam remeandering, bank grading, riffles/grade control, riparian buffer strips and other actions); and stream improvement that relies solely on riparian buffer corridors (i.e., no other actions). Given the limitations of the project schedule, alternative mitigation sites have not been finalized for stream restoration. For this analysis, benefits of stream restoration are based on potential habitat conditions for a hypothetical reach in the project area. A Cost Effectiveness and Incremental Cost Analysis (CE/ICA) was performed with these two stream restoration alternatives to compare which provided the best option for mitigation using habitat restoration. The Corps has and continues to coordinate with local agencies to identify potential sites for stream restoration. Preliminary candidate sites have been identified, and additional sites will be pursued in the months ahead.

For fish passage restoration, 13 dams have been coarsely reviewed for the potential cost and benefits of constructing fish passage. The costs and benefits of these different fish passage projects are provided below. A CE/ICA was then performed to identify alternatives that may be most appropriate for offsetting project impacts.

Connectivity Impacts

Fish passage channels will be constructed to minimize connectivity impacts identified under all alternatives. Under the FCP and ND35K, fish passage channels would likely reduce impacts to levels that would be less than significant. For these two alternatives, additional measures would not be pursued for connectivity impacts.

Under the LPP, there is an elevated risk for additional connectivity impacts that could require additional mitigation. To address this remaining impact under the LPP, measures were considered for improving connectivity at other locations. Fish passage would be the best mitigation option in terms of replacing the specific habitat value or function lost. The dams considered for fish passage are identified in Figure 1. These 13 dams were evaluated and compared to determine which would provide the greatest benefits in terms of replaced connectivity, relative to their potential cost.

Mitigation Alternative 1: Full Stream Restoration

For this analysis, benefits of full stream restoration are based on potential habitat conditions for a representative reach in the project area. Within the project area, streams have IBI ratings ranging from "very poor" to "good," with channelized streams likely being towards the middle or lower end of that range. It is assumed that candidate sites for stream restoration would be channelized streams having an IBI classification of "poor" (score of 0.3). Stream restoration would improve habitat and corresponding IBI scores. For the purpose of this assessment, it is assumed that restoration would improve habitat by one IBI classification. In this case, habitat would improve from "poor" to "fair" (score improvement from 0.3 to 0.55). Improvements would occur over time, potentially as shown in Table 7. It should be emphasized the improvements assumed here are based on professional judgment. While improvements could be more or less dramatic, other factors such as watershed land use, water quality, habitat fragmentation and other issues also limit the level of improvements in habitat quality for any individual site.

Table 7Potential quantitative habitat scores over a 50-year project life for hypothetical areas that could be targeted for stream restoration.

Year after implementing mitigation	YR 0	YR 1	YR 5	YR 10	YR 25	YR 50
IBI Score	0.30	0.32	0.40	0.50	0.55	0.55

Stream width varies by stream and reach. For the purpose of this analysis, it is assumed that a stream restoration site would have a top width of 50 feet. Though sites could be wider, assuming a narrower width is more conservative and provides a measure of safety for cost estimation.

Within the Red River basin, rivers and streams have a sinuosity ranging from 1.0 to at least 2.6. For this analysis, it is assumed that stream re-meandering would begin with a stream with a sinuosity of 1.0 (channelized stream), and end with a sinuosity of 2.0. This means that the amount of aquatic habitat could basically be doubled through stream re-meandering.

Given these assumptions, 24 acres of channelized stream habitat would be required to create about 17 AAHUs necessary to offset footprint impacts that would result from the LPP and ND35K alternatives. The preliminary estimated cost for this type of effort is $11.1M (Tables Table 8 and Table 9). Similarly, 21 acres of channelized stream habitat would be needed to create about 15 AAHUs necessary to offset footprint impacts from the FCP. Based on the same assumptions, the preliminary estimated cost for this effort is $9.7M.

Table 8 Potential habitat return and associated costs that could be realized through restoration of 24 acres of stream habitat for alternatives under a LPP or ND35K alternative. The pre-project acreage for restoration (24) was rounded up to the nearest whole acre needed to get at least 16.9 AAHU. This explains why the net future AAHUs (17.6) is slightly higher than the impacted AAHUs (16.9).

Re-meander Pre-Project Area (ac)	Re-meander Post-Project Area (ac)	Future W/O AAHUs	Future AAHUs	Net Future AAHUs	Alternative Cost	Average Annual Cost	Cost per AAHU
24*	48	7.2	24.8	17.6	$11,108,911	$528,240	$30,068

*Equates to about 4 miles of channelized stream restored, based on an average top width of 50 feet, and other listed assumptions.

Table 9<u>Assumptions for River Restoration Alternative Cost Estimate</u>

Assume 1/2 mile corridor needed, with 1/4 mile on each side of stream. This equates to 320 acres per mile of stream restored.
Assume 25% contingency on area of land to be purchased to account for flexibility for transactions. This results in 400 acres per mile of stream restored.
Assume the need to establish vegetation buffer of 150 feet on each side of the stream. This equates to 36 acres of land per mile of stream restored.
Assume channelized stream with incorporated meanders. Sinuousity would increase from 1.0 to 2.0 after restoration.

<u>Cost Assumptions:</u>

$4,000 per acre for real estate costs
$4,000 per acre for revegetation costs
$500,000 per mile for grading, structures and rip rap to recreate riffles and meanders

<u>Cost Distribution</u>

Real Estate: $1,600,000

Revegetation:	$144,000
Grading:	$500,000
Total:	$2,244,000
Contingency 25%:	$561,000
Total Cost per Mile	**$2,805,000**

Acres of Aquatic Habitat per Mile at Assumed Stream Top Width of 50 feet:
6 aquatic acres pre-restoration; 12 aquatic acres post-project

Mitigation Alternative 2: Stream Restoration via Riparian Buffer Corridors

For this analysis, benefits of riparian buffer corridors on potential habitat are considered for a representative reach in the project area. The level of improvement for the buffer strip alternative would likely be less than that identified above for full stream restoration. It is assumed that candidate sites for riparian buffer strips would be channelized streams having an IBI classification of "poor" (score of 0.3). Riparian buffer strips would improve habitat and corresponding IBI scores. For the purpose of this assessment, it was assumed that restoration would improve habitat by half that of the full restoration alternative. In this case, habitat would improve from 0.3 ("poor") to 0.42 (between "poor" and "fair"). Improvements would occur over time, potentially as shown in Table 10, it should be emphasized the improvements assumed here are based on professional judgment. While improvements could be more or less dramatic, other factors such as watershed land use, water quality, habitat fragmentation and other issues also limit the level of improvements in habitat quality for any individual site.

Table 10 Potential quantitative habitat scores over a 50-year project life for hypothetical areas that could be targeted for stream restoration.

Year after implementing mitigation	YR 0	YR 5	YR 10	YR 25	YR 50
IBI Score	0.30	0.35	0.40	0.42	0.42

Stream width varies by stream and reach. For the purpose of this analysis, it is assumed that a stream restoration site would have a width of 50 feet. Though sites could be wider, assuming a narrower width is more conservative and provides a measure of safety for cost estimation.

Given these assumptions, 165 acres of stream habitat would require buffering to improve habitat enough to create the 17 AAHUs necessary to offset footprint impacts that would result from LPP or ND35K alternatives. The preliminary estimated cost for this type of effort is $12.3M (Table Table 11). Similarly, 147 acres of stream habitat would require buffering to create the approximately 15 AAHUs needed to offset impacts that would result from the FCP. Based on the same assumptions (Table 10), the preliminary estimated cost for this effort is $10.9M.

Table 11 Potential habitat return and associated costs that could be realized through buffering 165 acres of stream habitat under the LPP and ND35K alternatives.

Buffer Pre-Project	Buffer Post-Project	Future W/O AAHUs	Future AAHUs	Net Future AAHUs	Alternative Cost	Average Annual Cost	Cost per AAHU

Area (ac)	Area (ac)						
165*	165	49.5	66.5	17.0	$12,252,475	$582,617	$34,282

*Equates to about 27.5 miles of channelized stream restored with an average top width of 50 feet.

Table 12._Assumptions for Riparian Buffer Alternative Cost Estimate.

Assume the need to establish vegetation buffer of 150 feet on each side of the stream. This equates to 36 acres of land per mile of stream restored.
Assume 50% contingency on area of land to be purchased to account for flexibility for transactions. This results in 54 acres per mile of stream restored.

Cost Assumptions:
$4,000 per acre for real estate costs
$4,000 per acre for revegetation costs

Cost Distribution

Real Estate:	$216,000
Revegetation:	$144,000
Total:	$360,000
Contingency 25%:	$90,000
Total Cost per Mile	**$450,000**

Acres of Aquatic Habitat per Mile at Assumed Stream Top Width of 50 feet:
6 aquatic acres pre-restoration; 6 aquatic acres post-project

Fish Passage Mitigation Alternatives:

For this analysis, benefits are based on habitat conditions made available with fish passage incorporated at potential dams identified on rivers with aquatic impacts. Both the habitat quantity and quality that would be made available are relevant to the analysis.

Many dams across the Red River basin impede fish movement. Thirteen potential sites for fish passages were initially identified through coordination with North Dakota Game and Fish Department. This includes Drayton Dam, where potential benefits would be shared by both North Dakota and Minnesota. Many additional dams are on Minnesota tributaries, and these could be favorable candidate sites as well.

To assess benefits from fish passage, dams with the potential to be candidate sites were first identified using both low-head dam points from State of North Dakota data and the USACE National Inventory of Dams. Then, stream area and stream quality that would be made available through fish passage were assessed.

Stream lengths were assessed through review of available stream networks in GIS (National Hydrology Data, NHD Medium Resolution, USGS). All stream areas upstream of a dam that could be made accessible to fish were quantified through use of stream networks. Available data on dams was combined with local insight to identify how far upstream fish would have access before encountering another dam. Stream lengths were then computed within GIS. Stream level information was determined by joining the primary GIS feature table to the NHDflowlineVAA table. Stream level was necessary to make a determination of the average stream width. Measurements were taken along numerous segments of each reach with the same stream level. Stream widths were measured through review of 2009 aerial photographs. Ultimately, stream areas were calculated by multiplying stream widths by stream lengths.

EPA (1998) provided IBI assessments of many stream reaches across the watershed. The IBI assessments are indicators of biotic integrity in these stream reaches, thus suggesting the quality of available habitat. To assess habitat quality in areas that would benefit from fish passage, the closest IBI observations were used for each tributary reach (Figure 1). Using the quantitative scores discussed above (Table 1), the applied quantitative score were multiplied by the acres of stream area to derive a total number of Habitat Units that would be provided through fish passage.

Given these assumptions, construction of fish passage could provide benefits that range from access to over 2,000 stream miles (over 7,700 HUs) to as little as 1.3 stream miles (4 HU) (Table 13). For cost estimation purposes, it was assumed that fish passage would be provided through the use of rock-riffle fishways across the entire width of the dam. These fishways have been used elsewhere in the basin and are believed to be passable to all species of fish under almost all hydrologic conditions. Using previous cost estimates as a guide, the preliminary estimated costs for this type of effort range from just under $2.0M to about $9.8M. It should be noted that costs can vary widely for these types of structures. Moreover, if dam removal is an option for constructing fish passage, than costs could be considerably less than those outlined here. The costs discussed here simply provide an initial estimate of the funds needed to construct fish passage at the dams identified.

Table 13 Potential habitat return and associated costs that could be realized through constructing fish passage at 16 various dams in the Red River Basin.

Dam	River	Estimated Cost	Avg Annual Cost (w/ O&M)	Stream Miles	Stream Area (acres)	Upstream Habitat Quality	Habitat Units (Q*AC)	Cost per Habitat Unit
Drayton	Red	$6,500,000	$314,082	2,167.8	14,575.1	0.53	7,724.8	$41
No Name 227	Maple	$4,470,000	$217,553	69.5	93.5	0.3	28.0	$7,760
Brownlee	Maple	$7,140,000	$344,514	211.0	314.4	0.38	119.5	$2,884
Lisbon	Sheyenne	$9,800,000	$471,000	54.7	248.8	0.55	136.8	$3,443
Kathryn	Sheyenne	$4,790,000	$232,769	11.9	64.1	0.55	35.3	$6,599
Warwick	Sheyenne	$2,670,000	$131,961	10.7	58.7	0.55	32.3	$4,091
Brown	Sheyenne	$3,130,000	$153,835	52.8	245.8	0.55	135.2	$1,138
Fort Ransom	Sheyenne	$5,990,000	$289,830	58.0	237.6	0.55	130.7	$2,218
Valley City Park	Sheyenne	$6,970,000	$336,430	1.3	8.1	0.55	4.4	$75,913
Valley City Mill	Sheyenne	$5,510,000	$267,006	47.9	194.2	0.55	106.8	$2,499
Soldiers Home	Sheyenne	$2,960,000	$145,751	6.2	24.3	0.55	13.3	$10,927
Wild Rice	Wild Rice	$6,860,000	$331,200	147.6	643.9	0.33	259.5	$1,276
Hanson	Wild Rice	$1,940,000	$97,249	277.0	1,208.6	0.1	120.9	$805

Aquatic Habitat Mitigation Alternative Comparison

To further compare the potential effectiveness of mitigation measures, the Corps performed a CE/ICA comparing the stream restoration alternatives, as well as fish passage alternatives. A Cost-Effectiveness (CE) analysis is conducted to ensure that the least-cost solution is identified for each possible level of environmental output (Orth, 1994). Cost effectiveness means that no plan can provide the same benefits for less cost or more benefits for the same cost. An Incremental Cost Analysis (ICA) of the least-cost solutions is conducted to reveal changes in costs for increasing levels of environmental outputs. Plans that provide the greatest increase in benefits for the least increase in costs are identified as "Best Buy" plans. In the absence of a common measurement unit for comparing the non-monetary benefits with the monetary costs of environmental plans, cost-effectiveness and incremental cost analyses are valuable tools to assist in decision-making.

The CE/ICA was performed with IWRPlan, available from the USACE Institute for Water Resources. IWRPlan assists with plan formulation by combining user-defined solutions to planning problems and calculating the effects of each combination, or "plan." The program can assist with plan comparison by conducting cost effectiveness and incremental cost analyses, identifying the plans which are the best financial investments and displaying the effects of each on a range of decision variables.

IWRPlan was run for the two stream restoration alternatives, comparing average annual cost to average annual benefits. Similarly, IWRPlan also was run for the various fish passage alternatives (i.e., each individual site) to compare their average annual costs and benefits.

A CE/ICA analysis was not performed to compare site-specific habitat restoration to fish passage alternatives. Although both analyses computed both average annual costs and benefits, the output metrics do not allow for a direct comparison within a CE/ICA. In other words, an AAHU for fish passage does not directly compare to an AAHU for site-specific habitat restoration. Although both forms of mitigation provide highly-valuable habitat values and functions, those values and functions are quite different, and do not easily compare to each other. Thus, these two restoration techniques will be qualitatively compared to each other below under *Mitigation Alternative Selection*.

Stream Restoration Alternatives

Comparison of the two stream restoration alternatives suggested a similar ratio of environmental output to cost Figure 2and Figure 3). While stream buffering is identified as "Non Cost Effective" (meaning it provides less environmental outputs environmental outputs for higher cost), the costs and benefits comparison was similar to full stream restoration. Of these two alternatives, full stream restoration would be given preference as a site-specific restoration measure. However, both measures could provide a similar level of value in terms of environmental output per unit of cost. Stream buffering will be considered for mitigation if full stream restoration cannot be used to fulfill needed mitigation.

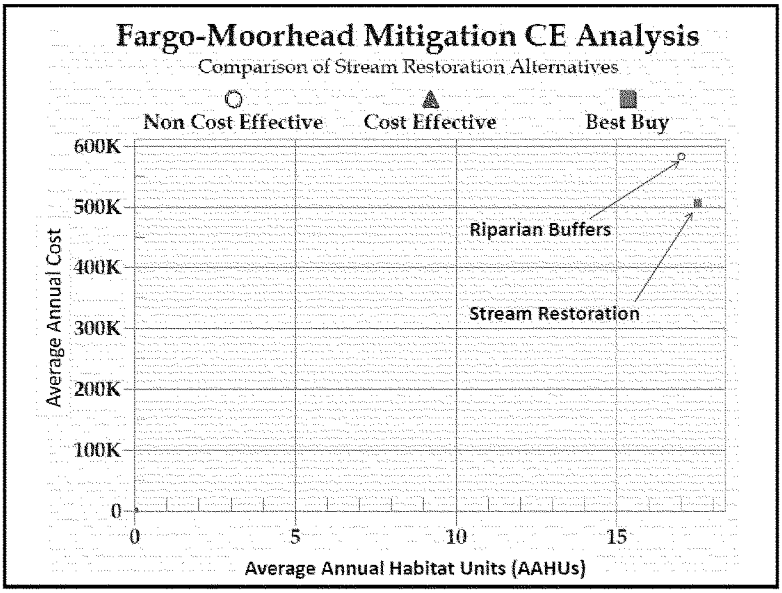


Figure 2 Cost Effectiveness analysis for the two stream restoration alternatives considered for mitigation of aquatic habitat impacts under the Fargo-Moorhead Flood Risk Management Study.

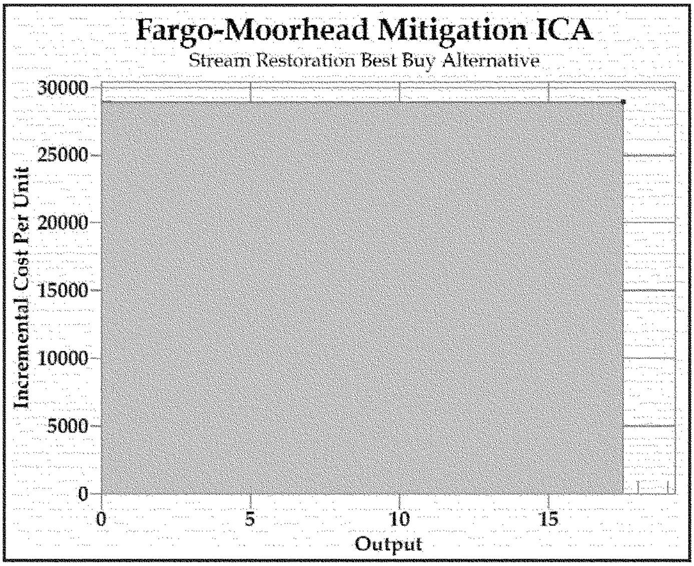


Figure 3 Incremental Cost Analysis for the single Best Buy stream restoration alternative considered for mitigation of aquatic habitat impacts for the Fargo-Moorhead Flood Risk Management Study.

Fish Passage Alternatives

Comparison of the 13 possible fish passage sites suggests Drayton Dam provides the greatest environmental output for the assumed cost (Figure 4 and Figure 5). Within IWRPlan, this is identified as a "Best Buy" Plan. Fish passage at Brown Dam and Hanson Dam also were identified from the remaining alternatives as being "cost effective" when considering costs and benefits. These two dams are, however, similar to other potential sites in terms of their value when comparing potential benefits for given economic costs.

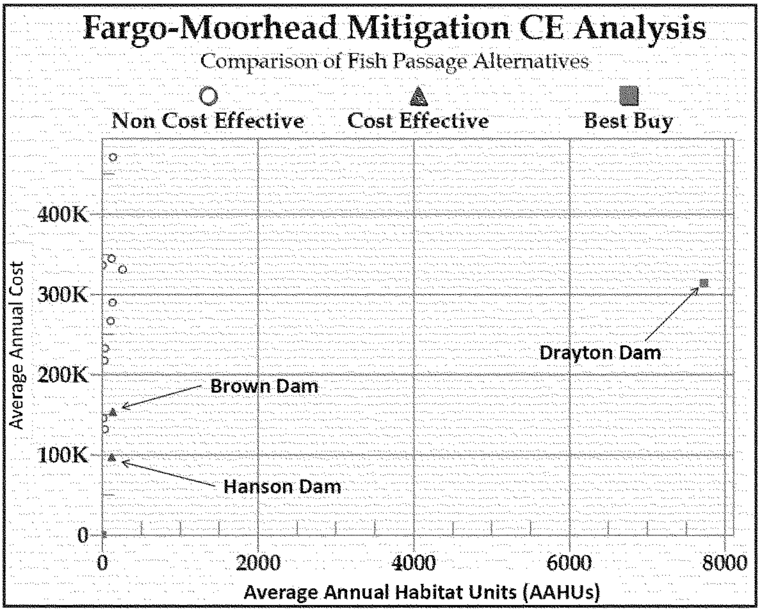


Figure 4 Cost Effectiveness analysis for 13 fish passage sites considered for mitigation of aquatic habitat impacts for the Fargo-Moorhead Flood Risk Management Study.

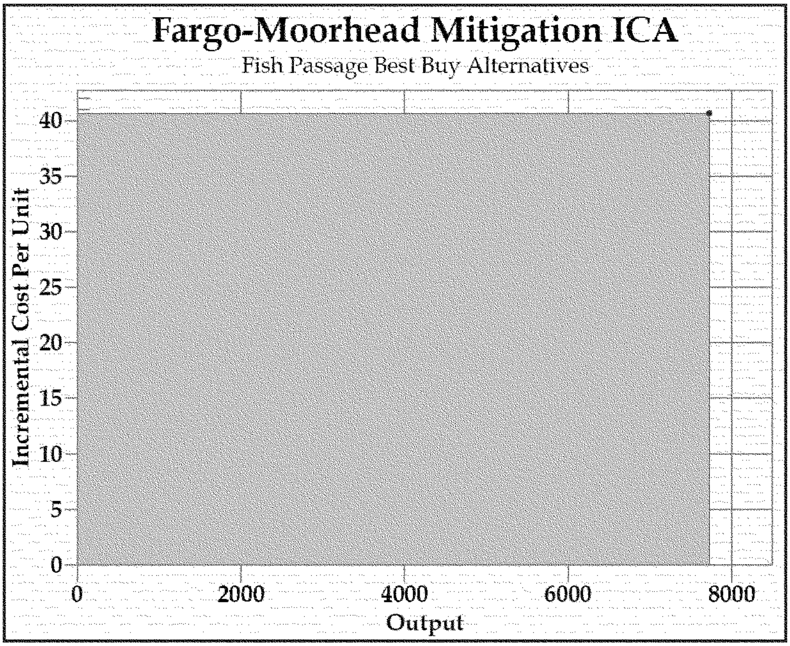


Figure 5 Incremental Cost Analysis for the Best Buy fish passage site considered for mitigation of aquatic habitat impacts for the Fargo-Moorhead Flood Risk Management Study.

Mitigation Alternative Selection and Implementation for Aquatic Habitat

Footprint Impacts

Site specific mitigation actions can improve habitat and be used to offset site-specific footprint impacts. However, such actions may be challenging to implement in this project area. Discussions with local resource managers suggests the likelihood of finding landowners willing to provide the real estate requirements for stream restoration could be low. Based on the assumptions made here, several miles of channelized, degraded habitat would be needed to offset impacts under any diversion channel alternative. Within the Red River basin, other outside efforts are assessing potential stream restoration activities. Possible mitigation sites include restoration projects along the Buffalo River, Wild Rice River and Mustinka River (Minnesota). It may be possible to use some of these sites for mitigation. Coordination with NRCS suggests additional sites with willing landowners may exist along the Sheyenne, Maple and Wild Rice rivers. However, even with these various options, many obstacles appear evident that could make implementation problematic.

NDGF and USFWS support a mitigation approach that considers both fish passage and site-specific stream restoration. Constructing fish passage will provide access to higher quality habitats. These benefits could be more substantial and meaningful for aquatic biota compared to restoration of individual stream reaches. The likelihood of finding willing landowners also appears higher for fish passage. In the case of Drayton Dam, a planning study currently underway for fish passage indicates that the Dam can be utilized as a mitigation site that will provide significant benefits. There are many dams that can be considered for fish passage, as outlined above; other dam owners will be consulted to determine their interest in participation. There are also many other dams outside of those identified that could be considered should the owners of the dams listed above not be interested in participating.

Given the challenges in identifying interested landowners, the following approach will be utilized. Site-specific stream restoration will first be pursued to offset identified aquatic impacts. To the extent practical, this form of mitigation will be used for impacts that are partially or entirely within Minnesota, including at least 7.6 AAHUs for the LPP and ND35K or 15.1 AAHUs for the FCP.

For site-specific aquatic impacts that occur on North Dakota tributaries, site specific habitat restoration opportunities will be pursued within similar areas. After site-specific habitat restoration opportunities have been thoroughly investigated, fish passage will then be considered to fill remaining mitigation needs for footprint impacts. Given the high value that fish passage appears to have, construction of fish passage should provide as many overall benefits, and be as effective, as site-specific restoration.

Connectivity Impacts

Potentially significant impacts to connectivity have been identified under the LPP for both the Red River and the Wild Rice River. To address these impacts, additional fish passages will be constructed at existing barriers on the river of concern.

To address connectivity impacts to the Red River under the LPP, multiple features will be constructed. First, six fish passage channels, in addition to the two fish passage channels that would be constructed with any of the diversion channel alternatives, will be constructed to provide connectivity during floods up to an approximate peak discharge of approximately 30,000 cfs (eight fish passage channels total for the LPP). These six additional channels would cost approximately $10M in total.

Next, to address any lingering concerns that fish passage channels are only partially effective at passing fish during a period of operation that could be a few weeks or longer, a fish passage at Drayton Dam will be constructed. This project would cost approximately $6.5M.This is the last remaining dam on the Red River in the United States, and would provide substantial connectivity benefits. Fish passage at this location would provide connectivity throughout the Red River mainstem during periods when Drayton Dam would typically be impassable. This occurs under conditions when the Red River is not flooding, and can occur frequently during the period May through July.

As additional information is gathered during the design and implementation phase, the mitigation may be optimized with a combination of equally effective measures to reduce this impact to levels that are less than significant.

To address remaining impacts to connectivity on the Wild Rice River, fish passage will be proposed at the Wild Rice Dam and the Hanson Dam. This will be fully coordinated with the natural resource agencies and dam owners to further verify appropriateness. The Wild Rice Dam would cost approximately $6.9M, and the Hanson Dam would cost approximately $1.9M. These are two low-head dams immediately downstream and upstream of the proposed control structure. Improving fish passage at these two dams will allow fish to pass these dams under all flow conditions. Currently, fish could only pass when these dams are washed out during high flows. The Wild Rice River structure under the LPP, as currently designed, would include two fish passage channels yet remain a complete barrier during portions of a flood when upstream water elevations would be mismatched with fish passage gate elevations. Constructing these two fish passage projects would mitigate this impact by providing passage across a broader period of time, and allow passage throughout the river when the project is not operating. Currently, these two dams are likely barriers during lower flow conditions. Construction of these two fish passage projects also would likely be more cost effective than constructing additional fish passage channels at the Wild Rice River control structure. Although a barrier would still exist, this would occur early during the spring when migrations are more limited. The two fish passage projects should provide significant benefits across most flow conditions, including periods later in spring and summer when larger migrations of fish are potentially occurring. Ultimately the proposed mitigation projects should offset connectivity impacts on the Wild Rice River.

3.2 Floodplain Forest Habitat Mitigation

Opportunities to acquire/manage existing riparian woodlands are considered to be almost non-existent and would not be a feasible approach for offsetting woodland losses associated with project construction. The interagency team agreed that the most feasible approach would be the acquisition of floodplain lands that are currently in agriculture or pasture, and re-establishing woodland on those tracts. The following objectives were identified:

1. Restore native floodplain forest and herbaceous vegetation. The floodplain forest should include green ash, cottonwood, black willow, hackberry, silver maple, American elm, American basswood, and bur oak.
2. Restore stand density with an average of 300 trees per acre over 80 percent of the mitigation site(s) with diameter at breast height (DBH) of 2 inches within 10 years. This tree density is typical for the Red River Basin floodplain forest in the project vicinity.
3. Restore floodplain forest community with a target species composition of at least 10 percent (by number of individual trees) bur oak and hackberry, with the rest a mix of green ash, cottonwood, black willow, boxelder, American elm, silver maple and American basswood.
4. Allow some regeneration of native herbaceous plants, shrubs, and trees from locally produced propagules on 20 percent of the mitigation land area, to create diversity in forest and herbaceous vegetation in the mitigation area.
5. Protect and manage the site(s) in perpetuity by an agreement for management as a wildlife management area by the Minnesota Department of Natural Resources or North Dakota Game and Fish Department.

Using the average HSI of .51 from section 2.3 and assuming the restoration occurs in a timely manner, the number of acres needed to replace the lost Average Annual Habitat Units would be 232 acres for the ND35K, 290.5 acres for the LPP or 130 acres for the FCP. Each species was also looked at separately to get a range of replacement ratios and number of acres to replace the lost habitat for each species (see Table 14). For example, to replace woodland that would support habitat for the Belted Kingfisher the mitigation requirement would be 191 acres for the ND35K, 239 acres for the LPP, or 107 acres for the FCP. Table 14shows the ratios for the other four models used for this analysis. Mitigation land would be planted with floodplain forest tree species representative of the impacted area.

Table 14 Ratios and acreages to replace per species.

Species	Ratio	ND35K	FCP	LPP
Belted Kingfisher	1.2 to 1	191	107	239
Gray Squirrel	2.07 to 1	329	184	412
Wood Duck	2.04 to 1	324	182	406
Black-capped Chickadee	1.93 to 1	307	172	384
Mink	1.15 to 1	183	102	99

None of the models used considered fragmentation, which is a concern because the forested land in this region is highly fragmented. For example, the models do not take into consideration forest connectivity and the width of the forested corridor. The project area has extremely long linear forested stands broken up by agriculture fields; there are very few areas in this region with large blocks of contiguous forested land. Based on the above sensitivity analysis, professional judgment, the absence of a community based model, the inability to capture the negative impacts of fragmentation, and the input from cooperating agencies, the team recommends a 2:1 ratio be used for mitigation for the lost forest. Therefore, it is recommended that 318 acres of agricultural land be converted to floodplain forest for the ND35K, 398 acres for the LPP, or 178 acres for the FCP.

Floodplain Forest Mitigation Restoration Objective and Alternatives

The primary objective of the mitigation is to restore floodplain forest. Alternatives include different restoration methods:

1) Acquire the mitigation land and direct seed with tree species, supplemented by planting seedlings of selected species as required.
2) Acquire the mitigation land and plant seedling trees
3) Acquire the mitigation land and let natural vegetation succession occur (no active restoration)

Alternative 1: Direct Seeding – Planting the site by direct seeding species that are readily available and planting bare-root seedlings of species that are not readily available has been found to be the most effective way to restore floodplain forest. The work would include woody debris removal, disking, herbicide treatment, and direct seeding with seeds of cottonwood (Populus deltoids), black willow (Salix nigra), green ash (Fraxinus pennsylvanica), hackberry (Celtis occidentalis), bur oak (Quercus macrocarpa), American elm (*Ulmus Americana),* silver maple (*Acer sacharinum*) and American basswood (Tilia americana). If seeds for any of these tree species are not available, those tree species would be planted as bare-root seedlings. Monitoring would be conducted and additional seedlings would be planted if the tree density targets are not attained.

Direct seeding appears to be the best option for a number of reasons:
- It produces a more natural looking forest
- It quickly produces a dense cover that shades out competition.
- By producing stem counts upwards of 15,000 seedlings an acre, rodents and deer should have a negligible impact on the planting.

Table 15 Alternative 1: Direct Seeding

Alternative 1: Direct Seeding				
Description	Unit	Unit Cost	Units per acre	Project Cost per acre year 1
Spring herbicide treatment (Roundup)	acre	$60	1	$60
Fall herbicide treatment (Roundup)	acre	$60	1	$60
Spring disking	acre	$20	1	$20
Spring herbicide treatment (Oust)	acre	$47	1	$47
Spread tree seeds	acre	$20	1	$20

Cottonwood seeds	ounce	$25	16	$400
Black willow seeds	bushel (fluffy)	$15	1	$15
Green ash seeds	gallon	$30	2	$60
Hackberry seeds	Lbs	$72	2	$144
Bur oak seeds	bushel	$50	2	$100
American basswood seeds	Lbs	$30	5	$150
O and M cost				$50
Fall herbicide treatment (Oust)	acre	$47	1	$47
Real Estate Cost				$4000
Total				$5173

Cost
Real Estate: $1,112,000 for 278 acres
Restoration: $326,094 first cost ($1173/acre)
Total average annual cost $75,716 (average annual cost/AAHU = $760.82)

The habitat value of this alternative would increase over time after planting, attaining a net increase of 27 AAHU over the 50-year planning period.

Alternative 2 – Plant seedlings - This alternative would include purchasing the mitigation land and restoration of floodplain forest by planting seedlings. The cost estimate was prepared assuming the worse-case scenario that the mitigation land would need a season of site preparation. The work would include woody debris removal, disking, herbicide treatment for at least 4 years, mechanical planting of seedlings, monitoring and additional seedling planting if necessary.

Table 16 Alternative 2: Seedling Planting

Alternative 2: Seedling Planting					
Description	Seedling age/size	Unit	Unit Cost	Units per acre	Project Cost per acre year 1
Mechanical tree planting		tree	$1	300	$300
Fall herbicide treatment		acre	$60	1	$60
Plow and disc site prep		acre	$20	1	$20
Plow and disc site prep previous summer		acre	$20	1	$20
American Elm seedling	12-18"	tree	$2	100	$200
Cottonwood seedling	12-18"	rooted cutting	$1	100	$100

Black willow seedling	12-18"	rooted cutting	$1	100	$100
Green ash seedling	2 years	tree	$0.30	100	$30
hackberry seedling	2-3 feet	tree	$2	100	$200
bur oak seedling	3-4 feet	tree	$2	100	$200
American basswood	18-24"	tree	$1.8	100	$180
O and M					$100
Real Estate Cost					$4000
Total					$5510

Cost
Real Estate: $ 1,112,000 for 278 acres
Restoration: $419,780 first cost ($1510/acre)
Total Average annual cost $76,760 (average annual cost/AAHU = $741.65)

The habitat value of this alternative would increase over time after planting, attaining a net increase of 32 AAHU over the 50-year planning period.

Alternative 3: Natural Vegetation Succession - This alternative would involve purchasing the real estate and site preparation. Most of the mitigation land area would be floodplain agricultural land lacking native vegetation. Over time, seeds and propagules would be brought into the area(s) by wind and during floods. Box elder and green ash may be the most abundant tree seed sources in the Red River basin. Over the course of as few as five years, most of the area would become densely colonized by box elder and green ash. Box elder exudes herbicidal metabolites from its roots, resulting in nearly monotypic stands with little ground cover. This condition would result in less than one third of the habitat value of a more diverse floodplain forest.

Table 17 Alternative 3: Natural Regeneration.

Alternative 3: Natural Regeneration					
Description	Seedling age/size	Unit	Unit Cost	Units per acre	Project Cost per acre year 1

Fall herbicide treatment		acre	$60	1	$60
Plow and disc site prep		acre	$20	1	$20
Plow and disc site prep previous summer		acre	$20	1	$20
O and M					$200
Real Estate Cost					$4000
Total					$4300

Cost
Real Estate: $1,112,000 for 278 acres
Restoration: $83,400 first cost ($300/acre)
Total average annual cost $60,782 (average annual cost/AAHU = $774.30)

<u>Floodplain Forest Mitigation Alternative Comparison</u>

To further compare the potential effectiveness of the mitigation measures, a CE/ICA was performed comparing the three alternatives for floodplain forest mitigation. For the CE/ICA the most current version of IWRPlan available from the USACE Institute for Water Resources was used. IWRPlan assists with the plan formulation by combining user-defined solutions to planning problems and calculating the effects of each combination, or "plan". The program assists with plan comparison by conducting cost effectiveness and incremental cost analyses, identifying the best buy plan, and determining whether the plans are cost effective.

IWRPlan was run for the three floodplain forest mitigation alternatives, comparing average annual cost to average annual benefits. Comparison of the three alternatives suggested that alternative 1 would be the best buy plan; however all of the alternatives are incrementally justifiable (Figure 6).

Alternatives 1 and 2 would establish diverse native floodplain forest on the mitigation land through restoration. Alternative 1 would be most likely of the three alternatives to succeed, given the experience with other floodplain forest restoration efforts on the upper Mississippi River in St Paul District. The majority of the mitigation cost would be for land acquisition. The measures to restore floodplain forest would be cost effective.

Alternative 3 would not meet the objective of restoring native floodplain forest. Following several years of dense annual weeds, boxelder (*Acer negundo*) would probably establish dense stands with lower habitat value than a more diverse native floodplain forest. Alternative 3 may be used in conjunction with the other alternatives for a portion of the mitigation properties.

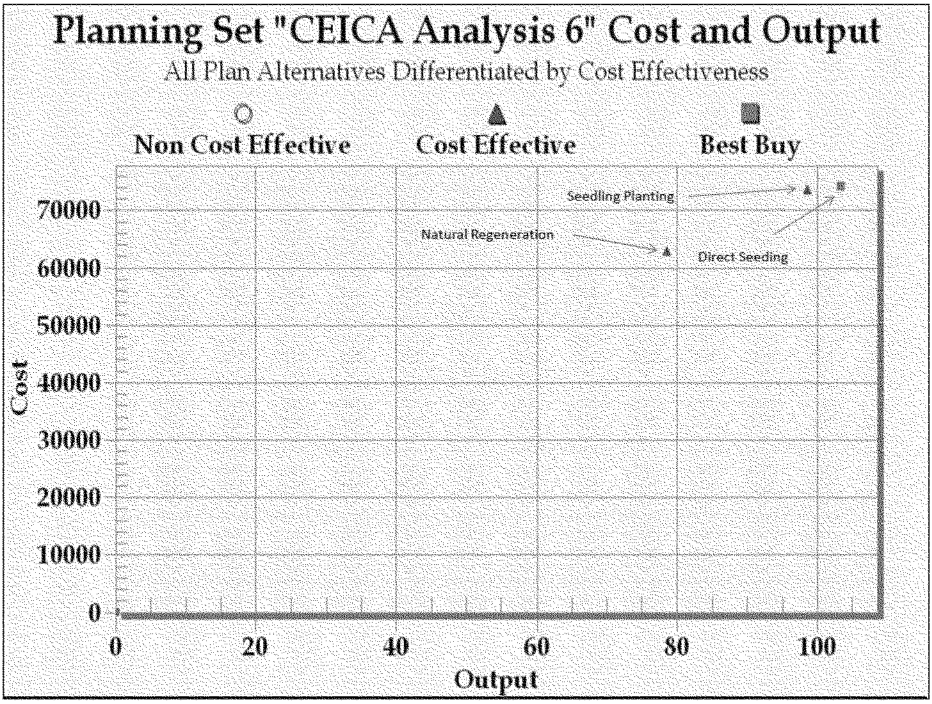


Figure 6 CE/ICA analysis for floodplain mitigation alternatives.

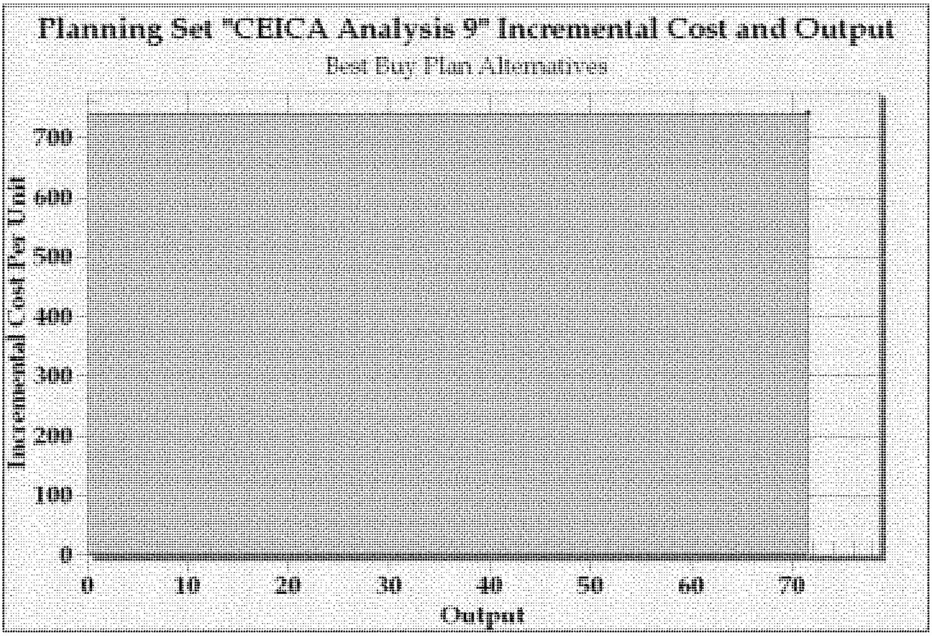


Figure 7 Incremental Cost Analysis for the Best Buy floodplain forest mitigation.

Mitigation Alternative Selection and Implementation for Floodplain Forest Impacts

Alternative 1, direct seeding, is selected as the best buy plan for floodplain forest mitigation. Upon purchasing the mitigation site(s), the Corps of Engineers and/or non-federal sponsors would conduct the following work:

1. Perform elevation survey and topographic mapping.
2. Prepare a detailed restoration plan with task list, schedule, budget and maps.
3. Delineate tree planting areas to cover at least about 80 percent of total area. The remaining 20 percent of the mitigation area would be allowed to grow in with native forbs, shrubs, trees and germinated from locally grown propagules. These areas of local vegetation would be interspersed between the tree planting areas.
4. Clear and grub the tree planting area and properly dispose of significant woody debris if necessary.
5. Treat the site with glyphosate after spring green-up and again in early fall.
6. The following spring, disc the site to expose mineral soil and treat with the pre-emergent herbicide Oust.
7. Direct seed the entire acreage with cottonwood (Populus deltoids), American elm (*Ulmus americana*), silver maple (*Acer sacharinum*), black willow (Salix nigra), green ash (Fraxinus pennsylvanica), hackberry (Celtis occidentalis), bur oak (Quercus macrocarpa),

quaking aspen (*Populus tremuloides*) and American basswood (Tilia americana). The site should then be lightly dragged to ensure good soil/seed contact. If large quantities of seed from any of the selected species are not available, the Corps would plant these species as bare-root seedlings. The bare-root seedlings would be planted by machine, and seedlings would be planted in meandering rows to better imitate a natural forest.

8. Assuming good germination and growth, apply Oust XP or another approved and appropriate herbicide in the fall after the seedlings go dormant to help ensure that there would be minimal weed problems in the following growing season.
9. If the direct seeding is not successful, plant seedling trees using power auger or tractor mounted tree planter. Install grow-tubes to protect against deer and beaver browsing and weed barrier mats to limit weed competition. Water the planted trees at planting and three more times within the next month if rainfall is less than 1 inch each week.
10. Monitor tree survival annually for 5 years.
11. Monitor tree survival and composition at 10 years. Replant as needed to attain target average of 300 trees per acre over the planted area with at least 10 percent hackberry and bur oak at 10 years after the initial planting.
12. If necessary, remove and properly dispose of the grow tubes when the trees reach 8 feet tall and more than 1 inch DBH.
13. Monitor tree survival and composition every 5 years thereafter and following major wind storms. Manage the forest to maintain the target tree density and composition.

3.3 Wetland Habitat Mitigation

The design of the diversion channel for each alternative includes a sinuous low-flow channel, which offsets the proposed loss of wetlands due to the project. The diversion channel alternatives have the opportunity to return lost functions back to the area. The low-flow channel within the diversion channel would be meandering, with a slope as low as .00013 for a sinuosity of 1.5. The channel would be planted with native wetland species on the bottom and the fringe of the side slopes of the channel, with the remainder of the side slopes being planted as a prairie swale type community. Appropriate native seed mixes may be those developed for ditch/swales, sedge/wet meadow or wetland fringe. A buffer strip of several hundred feet on either side of the diversion channel up to the embankment top would help limit encroachment from agricultural activities and would provide filtering of surface runoff into the diversion channel wetlands. Grade control structures would be required to avoid erosion during high flow events in the diversion channel. These structures would also benefit the creation of wetlands.

Creating and restoring wetlands within the diversion channel footprint will increase the ability of the landscape to retain and treat flood and storm water. Wetlands within the diversion channel, no longer subject to regular farming, will reestablish natural vegetation that will increase the water quality within the wetland, resulting in improved downstream water quality. This natural vegetation will also improve wildlife habitat in the area, providing refuge for wildlife and increasing diversity of species seen in the area. Given the quantity and quality of wetlands that would be created within the diversion channel , no additional mitigation is proposed for wetland resources. This large corridor of wetland habitat will be a continuous habitat corridor that rarely exists in this region, which will make it very desirable to a wide array of existing wildlife species.

Functional Assessment of Proposed Wetland Mitigation

Wetland areas to be created within the proposed diversion channel were analyzed using the Minnesota Routine Assessment Methodology for Evaluating Wetland Functions (MnRAM), Version 3.3. Based on the design of the diversion channel, a base flow is assumed within the channel bottom in most years, resulting in flow-through/riverine shallow marsh wetlands within the lowest portions and behind the periodic grade controls and fresh wet meadow wetlands dominating the remaining area below the upland slope. Wetland areas will be planted with native seed mixes appropriate for the intended plant communities and managed for invasive species such as reed canarygrass (*Phalaris arundinaceae*) and purple loosestrife (*Lythrum salicaria*).

When overall wetland functions are considered, the wetland development associated with the LPP is expected to fully offset any losses associated with project construction. Wetlands within the proposed diversion corridor will not be subject to the regular disking/plowing for agricultural production to which the majority of the existing wetland resources are subject. The replacement of wetland functions lost will be done within the same watershed as the impacts, adequately addressing some of the needs of the watershed.

The wetlands within the diversion corridor are expected to provide at least a "Moderate" level of functionality for *Maintenance of Hydrologic Regime, Flood/Stormwater/Attenuation, Downstream Water Quality, Maintenance of Wetland Water Quality* and *Aesthetics/Recreation/Education/Cultural* functions and values. Of course, the intent of the project itself is for flood damage attenuation, and the standing vegetation will provide for uptake of nutrients as well as longer retention of floodwaters than unvegetated conditions. The base flow in the channel will provide for sustained maintenance of hydrology within the corridor as well as to downstream resources, except in periods of extreme drought. The corridor will be visible from many public vantage points, providing an aesthetic improvement with the native vegetation and a naturalized meandering stream channel.

The wetlands will likely provide a "High" level of function for *Shoreline Protection*, situated as they are along the base flow channel. The naturalized vegetation, left untouched except for management of invasive and woody species, will maintain the streambanks by preventing erosion during the periods of high flow expected within the diversion corridor. Other "High" levels of function provided by the diversion channel wetlands include *Maintenance of Characteristic Wildlife Habitat Structure* and *Maintenance of Characteristic Fish Habitat*. Each of these functions would be enhanced by the standing vegetation and the uninterrupted wildlife corridor provided within the diversion corridor. Only the function of *Maintenance of Characteristic Amphibian Habitat* would be provided at a "Low" level, due to the direct connection to fish habitat from area rivers.

3.4 Total Proposed Mitigation

The total mitigation proposed for the diversion channel alternatives is listed in Table 18.

Table 18 Mitigation costs and Impact Magnitude

Resource	Impact Type	Impact (acres)	Impact (AAHUs)	Alternative	Mitigation Action	Cost
Red River	Aquatic Footprint	14 acres	7.6	LPP; ND35K	Stream Restoration	$5,000,000
Red River	Aquatic Footprint	30 acres	15.1	FCP	Stream Restoration	$9,700,000
Wild Rice River	Aquatic Footprint	12 acres	1.2	LPP; ND35K	Stream Restoration	$790,000
Sheyenne River	Aquatic Footprint	8 to 9 acres	4.6	LPP; ND35K	Stream Restoration	$3,100,000
Maple River	Aquatic Footprint	11 acres	3.2	LPP; ND35K	Stream Restoration	$2,100,000

Wolverton Creek	Aquatic Footprint	0.3 acre	0.2	LPP: ND35K	Stream Restoration	$110,000
Red River	Connectivity	Portions of hydrograph w/ complete disconnect		LPP	Implement additional fish passage channels	$ 10,000,000
Red River	Connectivity	Hydrograph for floods above 9,600 cfs at least partially impeded		LPP	Construct Drayton Dam Fish Passage	$6,500,000
Wild Rice	Connectivity	Portions of hydrograph w/ partial or complete disconnect		LPP	Construct Wild Rice Dam and Hanson Dam Fish Passage	$6,900,000 + $1,900,000
Study Area	Wetlands	910 acres		FCP	Wetland Restoration	18,100,000
Study Area	Wetlands	890 acres		ND35K	Wetland Restoration	17,900,000
Study Area	Wetlands	990acres		LPP	Wetland Restoration	19,960,000
Study Area	Forest	89 acres		FCP	Forest Restoration	890,000
Study Area	Forest	159 acres		ND35K	Forest Restoration	1,590,000
Study Area	Forest	199 acres		LPP	Forest Restoration	1,990,000
Total:					LPP	$58,350,000
					FCP	$28,690,000
					ND35K	$30,590,000

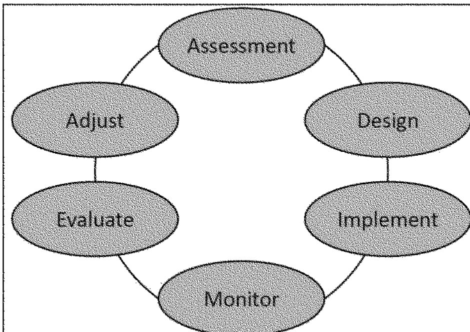
3.5 Additional Mitigation Measures for Consideration

In addition to those techniques outlined above, the non-federal sponsors and the Corps will look at other measures to avoid, minimize and compensate for project impacts. This could include similar projects at different locations, entirely different measures, or some combination therein. For example, one option that will be evaluated is the concept of passing more water through the protected area (e.g., discharges above 9,600 cfs at Fargo), by including in-town levees. Such a measure may reduce the frequency that the project needs to be put into operation. The costs for this action and the benefits provided will be compared to other mitigation features to identify if this action warrants implementation as mitigation. In-town levees and other actions will be considered during the design phase and coordinated with the sponsor and agency partners. Any alternative mitigation measures would need to generally fit within the total costs identified above, including contingencies. Additional NEPA documentation will be completed should it be required.

4. Adaptive Management

4.1 Adaptive Management Approach:

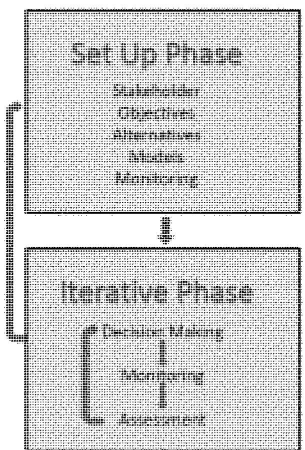
The purpose of this section is to begin laying out an adaptive strategy for a successful monitoring program in support of the project. Adaptive management (AM) is a "learning by doing" management approach which promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood (National Academy of Sciences 2004). It is used to address the uncertainties often associated with complex, large scale projects. In AM, a structured process is used so that the "learning by doing" is not simply a "trial and error" process (Walters, 1986).



Source: Nyberg, B. 1999.

The basic elements of an AM process are: (1) Assess; (2) Design; (3) Implement; (4) Monitor; (5) Evaluate; and (6) Adjust. In practice, AM is implemented in a non-linear sequence, in an iterative way, starting at various points in the process and repeating steps based on improved knowledge.

Application of AM should occur in two phases as suggested by the *Adaptive Management: U.S. Department of the Interior Technical Guide (2007)*. A setup phase would involve the development of key components and an iterative phase would link these components in a sequential decision process. Elements of the set-up phase include: stakeholder involvement, defining management or mitigation objectives, identifying potential management or mitigation actions, identifying or building predictive modeling or assessment tools, specifying performance measures and/or risk endpoints, and creating monitoring plans. In addition, values for the monitored measures that would trigger AM should be determined in this phase. The iterative phase uses these elements in an ongoing cycle of learning about system structure and function, and managing based on what is learned. The elements of the iterative phase include decision making, follow-up monitoring, and assessment.



Source: Williams, B.K., R.C. Szaro, and C.D. Shapiro. 2007

4.2 Establish an Adaptive Management Team

An Adaptive Management Team (AMT) would provide essential support to the project in meeting its goals and objectives through the application of a systemic approach to evaluating project impacts, mitigation and mitigation effectiveness. The AMT should consist of a multi-agency (State and federal) staff from the appropriate disciplines, including engineering, planning, environmental science and resource management. The non-federal sponsors would participate directly on the AMT and serve as the AMT leader. The exact members of the AMT will be determined during development of detailed project plans, but would likely include: the Corps, non-federal sponsors, U.S. Fish and Wildlife Service (FWS), Environmental Protection Agency (EPA), Natural Resource Conservation Service (NRCS), North Dakota Game and Fish (NDGF), North Dakota Department of Health (NDDoH), North Dakota State Water Commission, Minnesota Department of Natural Resources (MnDNR) and Minnesota Pollution Control Agency (MnPCA). The AMT would oversee the decision–making processes to plan and evaluate project features and mitigation to ensure project impacts remain less than significant.

4.3 Establish Goals, Objectives and Performance Standards Metrics

Clearly focused and quantitative goals and objectives are essential to AM. They should be logically linked to mitigation actions, action agencies, indicators/metrics, monitoring activities, and ecosystem values. Goals and objectives will be specifically identified during detailed mitigation planning. These goals and objectives will be critical elements of the project, with implementation concurrent with overall project construction.

Performance metrics would be used during two AM processes: plan evaluation (evaluation performance measures and metrics like those described above to predict project impacts) and assessment of actual plan performance (assessment performance measures following project implementation). In many cases, these processes would be the same, allowing predictions to be compared to actual responses.

Performance standards/metrics are further discussed in Section 6. This includes potential metrics for quantifying impacts following project construction, and how mitigation effectiveness will be measured. These standards/metrics will be fully developed based on input from the AMT during future planning for monitoring and evaluation. At a minimum, the goal of mitigation will be to replace the habitat value lost through project impacts. Performance standards/metrics will allow for this evaluation of mitigation effectiveness.

4.4 Develop and Implement Monitoring Plans

The CEQ NEPA Task Force (CEQ 2003) suggests that the effectiveness of adaptive management hinges upon an effective monitoring program to establish objectives, thresholds, and baseline conditions. This will be achieved through a stepwise process that includes both pre-construction studies of biota and physical habitat, and post-construction studies of biota and physical habitat. These studies are scheduled for both impact and mitigation sites, allowing impacts to verified, and for mitigation effectiveness to be evaluated.

Monitoring programs are a key component of AM. Monitoring provides feedback between decision making and system response relative to management goals and objectives. An essential element of AM is the development and execution of a scientifically rigorous monitoring and assessment program to analyze and understand system response to project implementation. It is recognized that project level monitoring would be limited by cost and duration based on current regulations and that project level AM plans would need to be designed to reflect this constraint. However, post project monitoring would be a part of project implementation, with monitoring required from the non-federal sponsors as a part of project operation and maintenance.

Following the adaptive framework of this document, impacts would be monitored over time and performance of measures would be assessed to determine whether additional avoidance, minimization, or compensation measures are needed. Future monitoring will provide information on the accuracy of the conclusions reached on the extent of impacts from the project features and evaluate the effectiveness of mitigation. Monitoring activities, including review of results, will be performed collaboratively with the AMT.

Pre- and post-project monitoring is discussed in greater detail below in Section 5. Specific proposed sampling methodologies are being designed to address the performance standards/metrics outlined in Section 6.

4.5 Contingency Plans

Post-project monitoring will include an evaluation of mitigation effectiveness. Should mitigation prove ineffective, or should impacts prove more significant than previously anticipated, then additional mitigation may be warranted.

The AMT must first identify which resources still have remaining impacts needing mitigation. This remaining impact should be quantified. Potential mitigation can then be identified to offset this remaining impact.

Funding mechanisms for implementing additional mitigation must then be identified. In some instances, recent large-scale projects constructed by the Corps of Engineers have included authorization language specifying a federal funding source for future mitigation needs. This has also included appropriation of such funds. Under these circumstances, projects have a specific mechanism to implement contingency mitigation plans in cases where project impacts have not been appropriately mitigated.

Unfortunately, contingency plans for mitigation are not included as an authorization of most projects, and are ultimately the decision of the U.S. Congress. At this time, it is assumed that the project would follow a typical authorization for Specifically Authorized Corps projects. In this case, federal project funding would be provided through construction and until the project is turned over to the non-federal sponsors. Thus, funding would be provided for construction of planned mitigation projects, and potentially some of the initial post-project monitoring. It cannot be guaranteed that federal funds would be available, specific to this project, for contingency mitigation.

The non-federal sponsors will be responsible for contingency mitigation. They may elect to collaborate with the AMT and other appropriate local, state and federal agency representatives to identify the appropriate funding source. This could include the use of local or State funds to address remaining mitigation needs. The non-federal sponsors could also coordinate with USACE for possible funding under the Corps' Continuing Authorities Program (CAP). The non-federal sponsors also could coordinate with their congressional leaders for authorization and appropriation of additional funds to address contingency mitigation.

5. MONITORING

The purpose of this section is to lay out the plan for pre- and post-construction monitoring. Monitoring will be done in concert with the overall adaptive management approach outlined above.

The purpose of monitoring is to better characterize pre-project conditions for key resources, characterize these resources following project implementation, verify resulting project impacts, and verify whether mitigation is offsetting these project impacts. An overview of methodologies is provided, and costs associated with monitoring is summarized in Table 19 and Table 20. Pre-construction monitoring efforts will be led by the Corps and the non-federal sponsors. Following construction, monitoring and adaptive management would be the responsibility of the non-federal sponsors. All monitoring will be done collaboratively with the AMT.

The monitoring approaches outlined below will need to remain flexible to adapt to the needs of the project. As such, this Adaptive Management Plan, including the monitoring plan is open to change. Modifications to the monitoring plan could be needed due to altered conditions either pre- or post-project; alternative technologies or techniques that become available for monitoring; and refinement of specific project features or mitigation actions. Monitoring costs will need to generally fit within those outlined here, including contingencies.

5.1 Aquatic Habitat:
Monitoring for aquatic habitat will be focused to answer the following specific questions:

1) What is the quality of aquatic habitat directly lost, or potential altered, through project features?
2) Has the project impacted physical aquatic habitat and physical river processes in areas where hydraulics or geomorphic conditions are changed?
3) How effective has mitigation been at offsetting impacts to aquatic habitat and biotic integrity?

These questions will be addressed within all impact areas for aquatic habitat. They also will be addressed for mitigation areas.

To address these questions the following field investigations will be performed:

1) Geomorphic assessments
2) Fisheries Assessments
3) Macroinvertebrate Assessments
4) Physical Habitat Assessments
5) Mussel surveys

Geomorphology

Geomorphic assessments will help answer the following specific question:

- Has the project impacted physical aquatic habitat and physical river processes in areas where hydraulics or geomorphic conditions are changed?

The tasks to be completed for geomorphology are outlined within a Scope of Work (SOW) protocol for performing the geomorphic assessment (available upon request). This includes analysis of hydrology, bank stability, sediment transport and morphological classification. Work under this SOW was initiated in 2010 and will continue in 2011, providing key pre-project observations that will form the basis for future comparison. In addition to work outlined in the SOW, additional data has been collected to support geomorphic assessments. This includes LIDAR data collected for the Red River basin during 2008 and 2009; bathymetric data collected in 2010 for the Red River from Abercrombie to Perley, Minnesota; and sediment transport data for the Red River and select tributaries during the spring flood of 2010. The USGS also has been contracted to collect additional sediment transport data from the Red River during spring of 2011.

The geomorphic study area will include the following locations in the project area (Figure 8and Figure 9):

- Red River of the North from Abercrombie to Perley, Minnesota
- Wild Rice River from Abercrombie, North Dakota to the Red River of the North
- Sheyenne River from Kindred, North Dakota to the Red River of the North
- Sheyenne River Diversion Channel from Horace to West Fargo, North Dakota
- Rush River from Prosper, North Dakota to the Sheyenne River
- Lower Branch Rush River from Prosper, North Dakota to the Sheyenne River
- Maple River from Mapleton, North Dakota to the Sheyenne River
- Buffalo River from 1 mile upstream of Georgetown, Minnesota to the Red River of the North
- Wolverton Creek for 3 miles upstream of the Red River of the North

Geomorphic surveys will be performed once prior to construction, and at least twice following construction. The results of these assessments will be compared to verify changes in geomorphic conditions, and the likelihood that any changes are due to the project. The timing of post-construction monitoring is still being identified. Geomorphic changes often are triggered by flood events. Thus, changes may not occur until one or more 50-percent chance events have occurred at a project site. As such, scheduling specific years for post-construction geomorphic surveys is difficult. However, the first post-construction assessment would potentially be five to ten years following project completion. The second assessment would potentially be twenty years following project completion. Additional future geomorphic surveys could be warranted, the need for which will be collaboratively discussed by the AMT.

Biotic Assessments

Biotic assessments will help answer the following specific questions:

- What is the quality of aquatic habitat directly lost, or potential altered, through project features?
- How effective has mitigation been at offsetting impacts to aquatic habitat and biotic integrity?

Biotic assessments will include a series of field investigations:

- Fisheries Assessment
- Macroinvertebrate Assessment
- Physical Habitat Assessment
- Mussel surveys

Biotic assessments outlined here will identify general biotic conditions of the project area. While there could be some seasonal variability in fish and macroinvertebrate use of select areas, the assessments outlined below are targeted at assessing the general biotic condition and integrity of the project area. Concerns with connectivity and associated monitoring are addressed separately below.

The general study approach for biotic assessments in impact areas will be a "Before-After-Test-Control" design, allowing multiple forms of comparison. First, sampling prior to and following construction will allow a "Before-After" comparison. Similarly, sampling areas potentially impacted by the project, as well as adjacent control sites, will allow a "Test-Control" comparison to further verify potential changes due to the project.

The study locations for biotic assessments will initially include those identified in Figure 10. These locations may shift based on further project design or site conditions. Sites will include areas directly within the project footprint, areas either downstream or upstream of project structures where hydraulics could change, and nearby control sites.

Post-construction surveys will include assessing biotic conditions within newly created stream channels that route flow through project structures. In the case of the Rush and Lower Rush rivers, these stream channels will be re-routed as a single channel in the bottom of the diversion channel. This new channel will be assessed at one or two locations post-construction. This approach will help determine habitat quality and biotic integrity within these new stream channels.

Additional surveys also will be performed in potential mitigation sites. However, since mitigation plans are still being refined, these survey locations have yet to be finalized. Stream restoration will be a primary mitigation method for aquatic impacts, with fish passage also providing mitigation. Monitoring will be needed to verify effectiveness of the mitigation. Mitigation sites will include pre- and post-project sampling. They also may include additional control sites. This plan will be updated as mitigation sites are finalized.

For each sampling site (Figure 10), the following activities will be performed.

1) Site Reconnaissance Investigation
2) Fisheries Assessment
3) Macroinvertebrate Assessment
4) Physical Habitat Assessment

The methodologies to perform the above sampling will largely be adapted from methodologies developed by NDDoH. Both states are developing respective fish and invertebrate IBI scoring systems for the Red River Basin, and these will generally be used to assess rivers in the respective states. Given that the majority of assessments will be performed in North Dakota, the DoH methodology will serve as the source for the majority of methodologies.

First, site reconnaissance will be performed to establish survey sites and identify appropriate sampling methods for fish, invertebrates and physical habitat based on survey site characteristics. The methodologies for site reconnaissance (available upon request) are from MnPCA. Site reconnaissance will be performed during June or July.

Fisheries assessments would then be performed following the fisheries sampling methodology developed by NDDoH (available upon request). Methodology for fish sampling is defined by whether the river is characterized as "wadeable" or "nonwadeable." Site conditions will dictate which sampling methodology is used. Methodology may need to be modified to accommodate rivers in the project area, some of which are likely borderline between being either wadeable or non-wadeable. Sampling in Wolverton Creek (MN) and the Red River also will follow the fish methodology outlined by NDDoH. Fisheries sampling for all sites will occur during the low-flow summer period (i.e., July thru September).

Macroinvertebrate surveys would then be performed by methodology also developed NDDoH (available upon request) for streams that can be characterized as "wadeable" streams. Methodology for all invertebrate sampling will follow that developed by NDDoH. For streams that are considered "non-wadeable" the methodology will be modified, if possible, to facilitate sampling. This could include sampling macroinvertebrates in near-shore areas that could be accessible by wading. Macroinvertebrate sampling from a boat also will be considered (methodology for all invertebrate sampling available upon request). If acceptable sampling conditions are not available, then macroinvertebrate sampling may be dropped from those survey sites. This could potentially be an issue on the Red River, as well as the larger North Dakota tributaries. The ability to perform macroinvertebrate sampling will be evaluated during both the site reconnaissance and fisheries assessments. A decision will be made at that time where macroinvertebrate surveys will be performed. This could result in some locations dropping from consideration for future macroinvetebrate sampling under this plan. Invertebrate sampling will occur after fisheries sampling during the low-flow summer period (i.e., July thru September).

Lastly, a habitat assessment will be performed to characterize in-stream habitat conditions. For wadeable streams, the MnPCA protocol to assess physical habitat and water chemistry will be used to characterize habitat. For non-wadeable streams, the MnPCA protocol for Stream Habitat Assessment (MSHA) will be followed (habitat assessment methodologies available upon request). These two methodologies will be applied to all rivers sampled. The methodologies are similar to those applied by NDDoH and provide a convenient set of methods for both wadeable and non-wadable streams. Habitat assessments will be completed after fisheries sampling has been completed.

Where needed, all of the above methodologies may be modified to adjust to site conditions. As outlined, river depths may warrant switching between protocol for wadeable and non-wadeable streams. River conditions also could require modifications to sampling equipment or methods. Survey station lengths may be modified, particularly in footprint areas where additional sampling may be done to cover an entire footprint area. Any modifications will be coordinated with the AMT and reflected within the more detailed Scope of Work that will be developed for executing sampling.

As of this report date, the locations, methodology and number of mussel survey sites are still being developed. Mussel surveys can be labor intensive, with mussel distribution often spotty or sparse, especially in poor habitat areas. The methods outlined above for macroinvertebrates will assess general biotic condition of the project area. However, to address remaining specific concerns for mussels, mussel surveys will be considered in footprint impact areas, and potentially other sites. Review of recent mussel survey data may help direct and streamline mussel sampling. Sampling methodology and survey sites will be coordinated with partner agencies.

Biotic surveys for fish and macroinvertebrates would be performed twice prior to construction. A third year of sampling will be considered based on results observed during the first two sampling efforts, and funding availability. A single sampling event for mussels would be performed. The timing of post-construction biotic monitoring is also under discussion, but will include at least two surveys performed over the first 20 years following project completion. Surveys would be performed in the same locations as those for the pre-construction surveys to identify any changes to habitat quality.

5.2 Aquatic Connectivity and Fish Passage Assessments:

Monitoring will be done to assess the effects of project features on fish migration. Monitoring for connectivity will be focused to answer the following specific questions:

1) Are fish able to find fish passage channels at the Red River control structure?
2) Are fish able to migrate through the fish passage channels at the Red River control structures?
3) How successfully do fish migrate upstream through the diversion channel?
4) Do fish successfully use the rock rapids fishway at Drayton Dam, or similar mitigation sites?
5) To what extent do fish seasonally use Wolverton Creek upstream of the proposed structure on this stream?

These questions will be addressed following project construction and operation. Observations for the Red River control structure could also represent similar success or failure of the fish passage channels at the Wild Rice control structure. However, monitoring specifically for the Wild Rice structure also may be performed. Similarly, monitoring will be done for at least one rock rapids fishway mitigation site, although all sites could be monitored, especially if designs differ substantially.

Monitoring to assess potential impacts to fish migration would be done once project features are in place and the project is put into operation (post-construction monitoring). No pre-project monitoring is currently planned to assess fish movements.

During coordination in winter 2010-2011, natural resource agencies expressed a preference to perform a comprehensive pre-project fisheries monitoring to assess fish migration. This would include detailed assessments to document the timing and duration of migration for most Red River species and movement of fish back forth between the Red River and project area tributaries. However, while this could be helpful information, a comprehensive pre-project migrational assessment is currently not planned for the following reasons. First, existing data is available to suggest the timing and duration of migration for several species in the Red River basin. Second, this report assumes fish have the ability to migrate freely through the upper Red River at any time under pre-project conditions. This includes assuming fish passage will soon be constructed at Christine and Hickson dams. Third, collection of detailed information on fish migrations would be expensive compared to other baseline monitoring. Fourth, data such as fish telemetry data is highly variable, and may not provide a substantial improvement over existing knowledge. For these reasons, the Corps concluded that pre-project monitoring for fish migrations would not be completed. This conclusion could be revisited if more cost-effective means are identified to collect such information.

Pre-project monitoring would be performed to assess potential connectivity impacts specific to Wolverton Creek. The specific methodology of this assessment is still under discussion, but could include a pre- and post-project assessment of seasonal fish community composition to assess if the project has influenced upstream fish communities.

For comprehensive post-construction monitoring of potential impacts to connectivity , the exact methodology for assessing this issue remains under discussion. However, monitoring could include activities such as netting, radio telemetry and/or hydroaccoustic monitoring.

Netting could be done immediately above the control structures or fish passage channels, and would provide insight into which species are able to migrate through these features. Netting is a fairly easy and inexpensive method to evaluate whether fish are able to pass through project structures.

Radio telemetry could be used to assess how many fish approach the structures, and what portions of those fish are able to migrate through these structures. This information would be extremely beneficial for not only assessing fish movement through project structures, but could provide general knowledge on effectiveness of features like fish passage channels and rock-riffle fishways that have not been evaluated in great detail. The drawback is that radio telemetry studies can be considerably more expensive, particularly for the equipment that is involved. It also requires the collection of fish and attachment or surgical implantation, which is labor intensive. Radio telemetry is biased toward larger bodied fish that can better handle the radio transmitter. There are also limitations in how long radio transmitters may last, which is problematic given that we do not know when there will be flooding events significant enough to activate the project.

Hydroaccoustic monitoring can detect the presence of fish much like a camera, but work effectively in turbid waters. Hydroaccoustic monitoring (e.g., imaging sonars such as the DIDSON) can monitor presence of fish below a potential impediment, and could monitor fish migration through structures. This technology has limitations in how effectively it may work under conditions with heavy debris flow. It also generally does not differentiate species of fish, only fish size.

It should be noted that the technology available for radio telemetry, sonar and hydroaccoustic monitoring is evolving rapidly. The tools available for assessing fish migration may be different (and improved) by the time the project is ready for operation. The exact methodology to evaluate fish migration has not been developed given this monitoring will not be performed until after the project is operational, and it will be at least 10 years until the project would operate. The AMT will further develop this specific methodology in the years ahead.

For the assessment of seasonal fisheries use of Wolverton Creek, pre- and post-project monitoring will be performed to assess potential impacts of reduced connectivity on Wolverton Creek. The specific methodology will be coordinated with the AMT, but would likely include fisheries sampling similar to that outlined above for wadeable streams. This evaluation would likely include at least two sampling events per year for multiple years both prior to and following construction. Differences in seasonal fish assemblages would be noted, and aid in confirming any impact of reduced connectivity by the project.

5.3 Fish Stranding:

Monitoring will be done to assess the effects of project features on fish stranding. Monitoring will include cursory visual assessments, following project operations, to observe potential for stranded fish. Observations will focus on likely problem areas, to include low areas in topography near the river channel upstream of the Red River and Wild Rice River control structures. Observations also will be made in the diversion channel. Observations will include notes on numbers, species and size of fish observed. This effort should be done collaboratively with resource agency partners. Observations would then be discussed within the AMT. At a minimum, these observations should be made following the first two or three events where the project operates. If substantial numbers of stranded fish are observed, a more rigorous assessment of fish stranding could be developed and employed to better quantify the number of fish stranded.

5.4 Floodplain Forest Habitat:

The majority of baseline data needed to quantify existing habitat value of floodplain forest impact areas has been collected (Appendix F). Additional surveys could be performed prior to construction; however these efforts would likely be small in scope. Following construction, survey transects would likely be established in floodplain forest mitigation areas to determine the condition of these habitat types and the overall effectiveness of their mitigation; see section 6 for a detailed monitoring plan and performance standards/metrics.

5.5 Wetland Habitats:

The National Wetland Inventory was used as a preliminary method to identify impacted wetlands; this information is what was reported in the DEIS. For the FEIS, a more detailed wetland determination has been conducted along the alignments for the diversion channel alternatives and included a MNRAM functionality assessment. This information was used to verify the mitigation approach for these wetlands. Surveys of the diversion channel will be performed to verify that wetland type and function present are offsetting wetland areas lost through construction.

Annual mitigation monitoring reports shall be submitted on the status of the mitigation. The reports shall be submitted by December 31 following each of the first five growing seasons. The reports shall, at a minimum, include the following information:

1. All plant species along with their percent cover, identified by meandering through each vegetative community, including upland buffers, and list commonly encountered – or dominant and co-dominant species observed. In addition, the presence, location and percent cover of invasive, noxious and/or non-native species in any of plant communities shall be noted.
2. Vegetation cover maps at an appropriate scale shall be submitted for each reported growing season.
3. Photographs showing all representative areas of the mitigation site taken at least once each reported growing season during the period of July 1 to September 30. Photographs shall be taken from a height of approximately five to six feet from at least one location per acre. Photos shall be taken from the same reference point and direction of view each reporting year. Location of the photographs should be mapped on a GPS unit

4. Surface water and groundwater elevations in representative areas (e.g., at least one sample point in each plant community) recorded at least once each week for the first 10 weeks of each growing season, thereafter taken monthly for the remainder of each growing season. The location of each monitoring site shall be shown on a plan view of the site.
5. If non-compliance activities are occurring on the site, make note of the activity, photograph the activity and map the location of the location of the non compliance activity on a GPS unit. Use your best professional judgment to determine if the activity is not compliance with easement or mitigation site plan.

A wetland delineation of the site applying the *Corps of Engineers Wetlands Delineation Manual, Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Great Plains Region (current version)* and guidance shall be submitted at the close of the monitoring period. This delineation shall be prepared by a wetland professional.

Over two-thirds of the wetlands that are impacted are seasonally flooded wetlands or farmed wetlands; these wetlands have very poor function. It is not environmentally preferable to compensate for impacts to degraded wetlands by deliberately providing degraded compensatory mitigation projects . A compensation project should result in high quality wetlands that provide optimum functions within its landscape context, taking into account unavoidable constraints. Typically the Corps requires impacts to even the most degraded wetlands to be mitigated at 1:1 (compensation acres: impact acres). In rare situations, the minimum compensation ratio can be lowered if it is determined that the impacted wetland is so degraded that it provides minimal wetland functions. Even though the wetlands impacted by the project are generally highly degraded they should be mitigated for by restoring equal acres of wetland or by restoring functions that are lacking in the Red River Basin watershed.

5.6 Cost Estimate for Project Monitoring:

A preliminary cost estimate for monitoring is provided in Table 19and Table 20 for the FCP and the ND35K and LPP. This is strictly a preliminary estimate of what survey costs could be to assess how well mitigation sites are actually performing. The monitoring costs for mitigation will continue to be refined, and could increase or decrease depending on the number and location of mitigation sites ultimately chosen. Costs for assessments specific to Wolverton Creek fisheries are included under the Connectivity costs in Table 20. Connectivity monitoring for Wolverton Creek would only be needed under the LPP. A specific line-item cost has not been included for observations for fish stranding under the LPP. Given this activity would be likely be a smaller effort limited to a few days, this would be accomplished by the non-federal sponsors as a part of project operations at the end of a flood. The effort should have a fairly small cost and as such is not included as a separate line item.

Table 19 Overview costs for monitoring, including post-construction evaluation of impacts and mitigation effectiveness, for the FCP.

Studies	Cost
Study Area Geomorphic Assessment: Pre-construction (1 event)*	$1,000,000
Study Area Geomorphic Assessment: Post-construction (2 events)	$1,000,000

Connectivity/Fish Passage Assessment: Post Construction	$5,000,000
Biotic Use: Pre-construction (3 events)	$2,250,000
Biotic Use: Post-construction (3 events)	$2,250,000
Diversion Channel Wetlands Monitoring Post Construction	$100,000
Total Pre-Project Monitoring	$3,250,000
Total Post-Project Monitoring	$8,350,000

*Costs for pre-project geomorphic surveys are based on work already underway. Pre-project surveys will be more extensive than needed for the FCP as survey work is being completed to cover all three diversion channel alternatives.

Table 20 Overview of costs for monitoring, including post-construction evaluation of impacts and mitigation effectiveness, for the ND35K and LPP.

Studies	Cost
Study Area Geomorphic Assessment: Pre-construction (1 event)	$1,000,000
Study Area Geomorphic Assessment: Post-construction (2 events)	$2,000,000
Connectivity/Fish Passage Assessment: Post Construction	$7,500,000
Biotic Use: Pre-construction (3 events)	$3,500,000
Biotic Use: Post-construction (3 events)	$3,500,000
Diversion Channel Wetlands Monitoring Post Construction	$100,000
Total Pre-Project Monitoring	$4,500,000
Total Post-Project Monitoring	$13,100,000

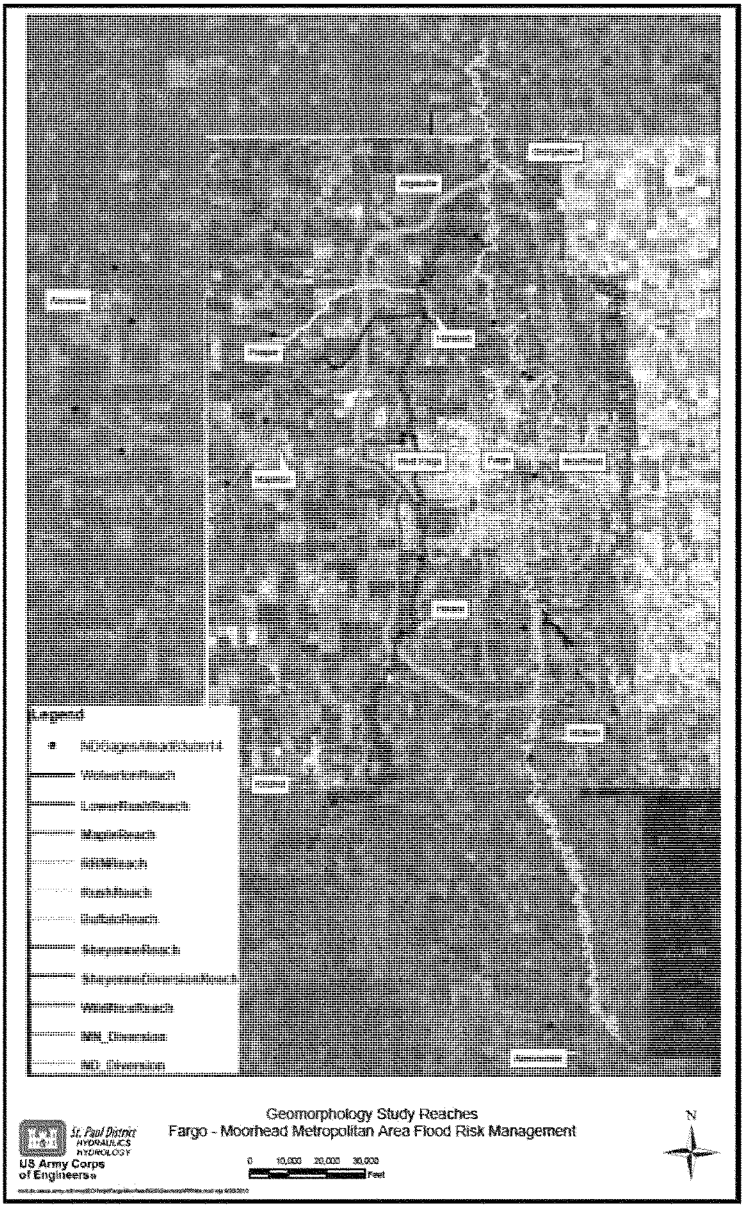


Figure 8 Geomorphic study reaches for pre-project monitoring.

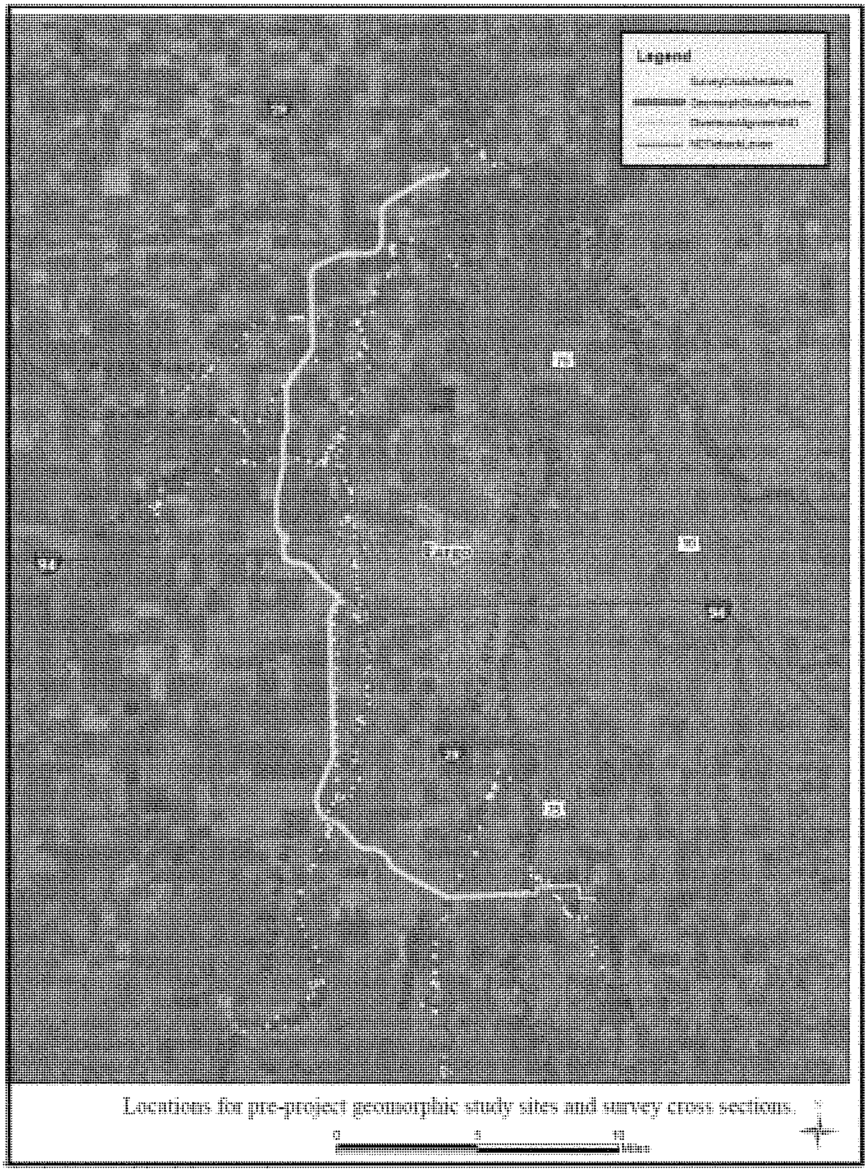


Figure 9 Geomorphic study reaches and survey cross-sections for pre-project monitoring.

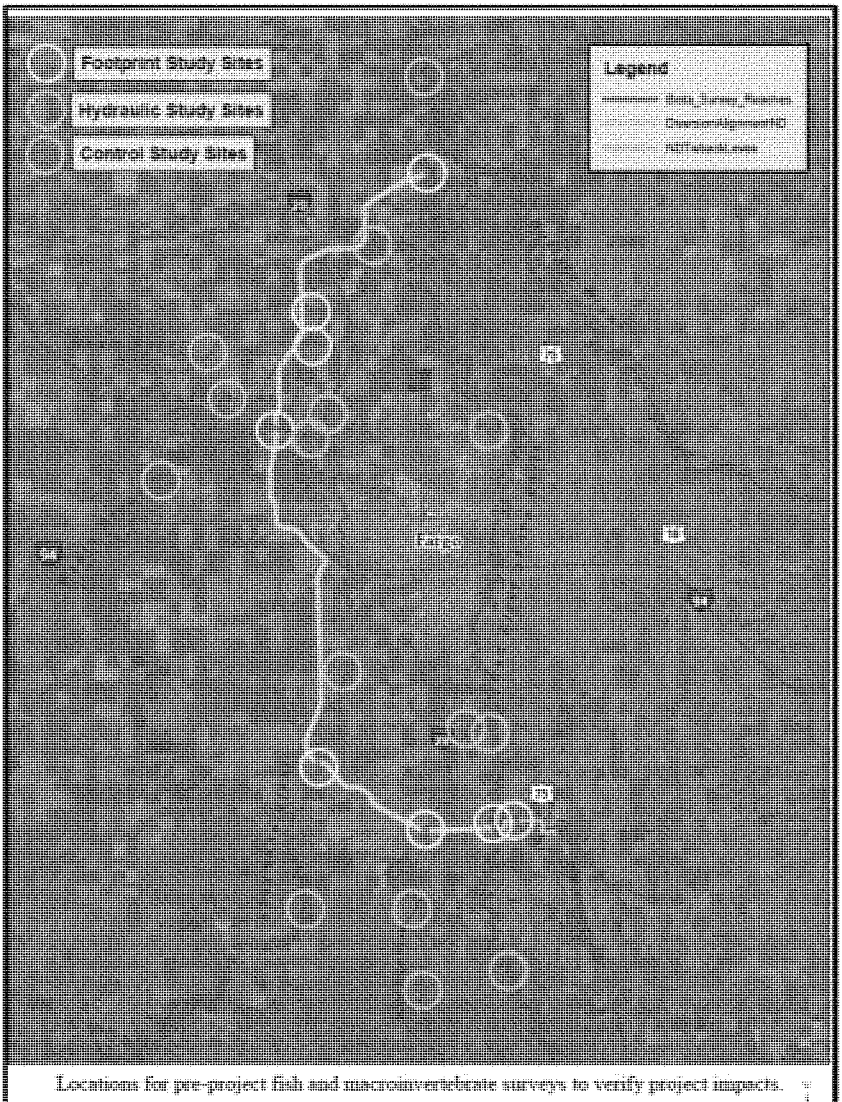


Figure 10 Biotic study reaches for pre-project monitoring. Biotic monitoring to include fisheries, macroinvertebrate and physical habitat observations at each identified site. Mussel survey may be performed at select sites.

6. Performance Standards/Metrics

Corps regulations require that projects develop and use criteria for determining ecological success of mitigation, and to ensure project impacts are offset. The exact criterion for verifying impacts and mitigation effectiveness is still under development for this project. However, there are several metrics under consideration. These are described below. It should be noted that multiple metrics may be needed to best describe project impacts and mitigation success. Relying on a single metric could under-estimate or over-estimate impact severity or mitigation effectiveness. Even with the use of several metrics, it is recognized that conclusions on project impacts and mitigation success will need to include detailed review of data and collaboration amongst the AMT. Even then, opinions may differ on the questions at hand. However, the discussion below provides insight into the types of metrics that could be used to verify project impacts and mitigation effectiveness. These metrics will continue to be developed over time through collaboration with the AMT.

Geomorphology

Impacts will be verified through collection of pre- and post-project geomorphic data. Factors such as channel stability, channel location and cross-sectional area, slope and other factors will be compared for potential change. Prior to construction, experts in geomorphology will be consulted to verify what level of change with these variables constitutes a significant geomorphic impact. This information will be coordinated with the AMT, and this plan will be updated as appropriate.

Performance Standards for Geomorphology:

1. AMT will collaborate on how best to identify and define significant change in geomorphic processes. This could include verifying the relative change needed in key variables, such as channel stability, cross section, slope, sediment transport, and other variables needed to conclude that significant changes have occurred to geomorphology.

Aquatic Habitat

Impacts will be verified through collection of pre- and post-project fish and invertebrate data. This data could be compared in several ways. At a minimum, an IBI score will be generated from project data, with scores compared before and after construction to verify resulting impacts. IBI scores also would be generated for mitigation sites to quantify the amount of mitigation created compared to the habitat lost through construction. An IBI scoring system had previously been generated in the Red River basin back in the 1990s to describe general biotic conditions (EPA 1998). Minnesota also is currently developing its own revised IBI scoring system for the Red River Basin. Both of these systems, and potentially other relevant IBIs, will be used to quantify biotic condition within impacted rivers. .

Impacts to aquatic habitat will be quantified by calculating a "Habitat Unit" as Impact Area multiplied by Habitat Quality (as identified from one or more of the above metrics). The effectiveness of mitigation will be determined as the Habitat Units lost through impact, compared to the Habitat Units gained through mitigation. This shall also take into account the Habitat Units that are present within any newly constructed river channels to facilitate routing flow through project features (e.g., water control structures, aqueducts, etc). The net result of impacts and mitigation should be at least zero Habitat

Units (break even between habitat lost through impacts and habitat gained through mitigation and newly created channels).

In addition to IBI scoring, project data will be summarized to produce various species richness and diversity indices. Relative abundance (e.g., Catch Per Unit Effort) also could be utilized to verify biotic condition of survey sites. These combinations of diversity and abundance could be compared pre- versus post-project, and impact versus control site, to verify project impacts and mitigation effectiveness. Considering multiple metrics may allow for a better comparison and determination of potential change due to the project. Whether any substantial changes have occurred will be determined collaboratively amongst the AMT.

Performance Standards:

1. Restore aquatic riverine habitat with an area and quantity needed to offset the loss of such habitat through footprint impacts. Using IBI scores as a quality indicator, calculate habitat lost/gained by the equation: IBI score X footprint area = Habitat Unit.

2. Similar metrics may be developed by the AMT that uses species diversity and relative abundance for impact areas and mitigation sites.

<u>Connectivity</u>

Impacts to connectivity will be assessed, although the effectiveness of fish passage and associated mitigation may be more subjective. At a minimum, mitigation must offset lost connectivity with restored connectivity. The AMT will collaboratively work to assess the effectiveness of mitigation. Similarly, mitigation that uses connectivity to offset site-specific aquatic habitat impacts will be evaluated by the AMT to consider effectiveness.

Performance Standards for Connectivity:

1. The AMT will collaborate on how best to identify and define fish passage effectiveness. This could include assessing the number of species observed to pass through a structure; and the relative percentage of a population that accumulates below a structure that is able to migrate around or through a structure.

For assessing potential impacts to Wolverton Creek connectivity, the specific metrics also will be developed through the AMT. Data would be reviewed to identify seasonal patterns in fish community composition prior to and following project construction. Differences in community composition could be due to the project, and would help verify potential impacts. The AMT can also assess whether additional mitigation would be warranted given upstream habitat needs and seasonal fisheries use that could be impeded with the project.

Performance Standards for Wolverton Creek:

1. Maintain similar seasonal fish community composition upstream of the Wolverton Creek structure prior to and following project construction. AMT will identify the level of change that

triggers a conclusion that community composition has changed prior to and following construction, and whether this change is due to the project.

Floodplain Forest

The monitoring results will be compiled, interpreted and described in letter reports. The monitoring reports will be provided to the partnering agencies and the public upon request.

Vegetation will be monitored annually for the first 5 years following planting using stratified random sampling. At each randomly generated point within the areas planted, plots of 0.01 acre will be surveyed. An average of at least one plot per acre will be surveyed. Tree survival and composition will be monitored every 10 years and following major flooding. Trees will be replanted as needed to meet the target vegetation cover (see Performance Standards below). Invasive and/or non-native plant species will be controlled for 3 full growing seasons. Control will consist of mowing, burning, disking, mulching, biocontrol and/or herbicide treatments as needed. By the third growing season, any planted areas one-half acre in size or larger that have greater than 50 percent areal cover of invasive and/or non-native species will be treated (e.g., herbicide) and/or cleared (e.g., disked) and then replanted with trees.

Performance Standards:

1. Restore native floodplain forest and herbaceous vegetation. The floodplain forest should include green ash, cottonwood, black willow, hackberry, silver maple, quaking aspen, American elm, American basswood, and bur oak.
2. Restore stand density with an average of 300 trees per acre over 80 percent of the mitigation site(s) with diameter at breast height (DBH) of 2 inches within 10 years. This tree density is typical for the Red River Basin floodplain forest in the project vicinity.
3. Restore floodplain forest community with a target species composition of at least 10 percent by number of individual trees to be bur oak and hackberry, with the rest a mix of green ash, cottonwood, black willow, boxelder, American elm, silver maple and American basswood.
4. Allow some regeneration of native herbaceous plants, shrubs, and trees from locally produced propagules on 20 percent of the mitigation land area, to create diversity in forest and herbaceous vegetation in the mitigation area.
5. Protect and manage the site(s) in perpetuity by an agreement for management as a wildlife management area by the Minnesota Department of Natural Resources or North Dakota Game and Fish department.

Wetlands

The monitoring results will be compiled, interpreted and described in letter reports. The monitoring reports will be provided to the partnering agencies and the public upon request.

Performance Standards:

Hydrology

1. **Seasonally Flooded Basins.** Hydrology shall consist of inundation by a few inches to 24 inches of water for a minimum of 14 consecutive days during the growing season under normal to wetter than normal conditions (70 percent of years based on most recent 30-year record of precipitation). Inundation shall be typically absent following the first 6 weeks of the growing season and soil saturation drops below 12 inches from the surface for the majority of the growing season in most years.

2. **Fresh (Wet) Meadows, Sedge Meadows and Wet Prairies (Mineral Soils).** Hydrology shall consist of saturation at or within 12 inches of the surface for a minimum of 30 consecutive days, or two periods of 15 consecutive days, during the growing season under normal to wetter than normal conditions (70 percent of years based on most recent 30-year record of precipitation). Inundation during the growing season shall not occur except following the 10-percent chance or larger event. The depth of inundation shall be 6 inches or less and the duration of any inundation event shall be less than 15 days. An exception can be made for sites with hummocky microtopography -- hollows between hummocks can have standing water depths of up to 6 inches for extended duration.

3. **Shallow Marshes.** Hydrology shall consist of saturation to the surface, to inundation by up to 6 inches of water, for a minimum of 60 consecutive days or two periods of 30 consecutive days or four periods of 15 consecutive days, during the growing season under normal to wetter than normal conditions (70 percent of years based on most recent 30-year record of precipitation). During the growing season, inundation by up to 18 inches of water following the 50-percent chance or larger event is permissible provided that the duration does not exceed 30 days (e.g., water depth drops from 18 inches to 6 inches within the 30 days).

4. **Deep Marshes.** Hydrology shall consist of inundation by 6 to 36 inches of water throughout the growing season, except in drought years (driest 10 percent of most recent 30-year period of precipitation record).

Vegetation

1. **Herbaceous Species Composition**:

   a. Fresh (wet) meadows, sedge meadows, wet prairies, and seasonally flooded plant communities (Type 1 and Type 2 wetlands) shall each achieve a species composition that includes 10 or more species of native/non-invasive grasses, sedges, ferns, rushes and/or forbs by year 5. Alternatively, a MnRAM vegetative diversity and integrity score of "high quality" by year 5 would also satisfy this performance standard.

   b. Shallow marsh and deep marsh plant communities shall be dominated by 3 or more native aquatic species, with at least 4 native plant species occurring within the shallow marsh communities on the site by year 5. A MnRAM vegetative diversity and integrity score of "high quality" for each these plant communities will also satisfy this performance standard.

c. Restored tallgrass prairie in the upland buffer and interior banks of the diversion channel shall be dominated by 3 or more species of native grasses, sedges, rushes, forbs and/or ferns, with approximately 80% or greater areal coverage of the total mitigation site, and at least 10 native species occurring within the area of the upland communities on the site by year 5.

2. **Hydrophytes.** More than 50% of all plant species within the wetland communities of the mitigation site shall be facultative (FAC) or wetter (FACW or OBL) excluding FAC-.

3. **Control of Invasive and/or Non-Native Species**: Control of invasive and/or non-native plant species shall be carried out for five full growing seasons. Control shall consist of mowing, burning, disking, mulching, biocontrol and/or herbicide treatments. By the third growing season, any areas one-quarter acre in size or larger that have greater than 50 percent areal cover of invasive and/or non-native species shall be treated (e.g., herbicide) and/or cleared (e.g., disked) and then reseeded. Follow-up control of invasive and/or non-native species shall be implemented as stated above.

Attachment 7

Fargo-Moorhead Metro

Final Feasibility Report and Environmental Impact Statement

July 2011

Electronic Copy of Main Report and Appendices

RED RIVER DIVERSION

FARGO-MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT

FEASIBILITY STUDY - PHASE 4

Volume 2

Appendix A

Report for the US Army Corps of Engineers
and the cities of Fargo, ND and Moorhead, MN

Prepared by:
US Army Corps of Engineers

April 2011

RED RIVER DIVERSION

FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4

Report for the US Army Corps of Engineers
and the cities of Fargo, ND & Moorhead, MN

US Army Corps of Engineers

VOLUME 2

APPENDIX A

FINAL – Version April 15, 2011

Appendix A
Hydrology

Fargo-Moorhead Metropolitan Area Flood Risk Management

Supplemental Draft Feasibility Report and Environmental Impact Statement

April 2011

US Army Corps of Engineers®

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Executive Summary

Need For Study. The Red River of the North has exceeded the National Weather Service flood action stage of 17 feet in 50 of the past 106 years at USGS gage site 05054000 located at Fargo, ND and every year from 1993 through 2010. Given the high risk of flooding along the Red River of the North, the St. Paul District of the US Army Corps of Engineers is completing a feasibility study of alternative measures to reduce flood risk in the Fargo –Moorhead Area. Appendix A of the Fargo-Moorhead Metro Feasibility Study (FMMFS) covers the hydrological analyses used to provide for economic analysis, identify design parameters and develop hydraulic modeling for this study.

Study Limits. The adopted Fargo-Moorhead Study limits for Hydrological analysis are from Hickson, ND to Emerson, Manitoba, Canada. The adopted study limits are reflected in Appendices A-2 through A-4 of the Fargo Moorhead Metro Feasibility Study Report. In Phase I of the study, it was thought that Wahpeton, ND was the most upstream limit and therefore analysis between Wahpeton and Hickson was included in Appendix A-1. Analysis upstream of Hickson was not carried forward in the remaining Appendices after the Expert Opinion Elicitation.

Project Evolution. The USACE carried out the Hydrological analysis for the FMMFS in four phases. The first phase of the study began with a draft report issued by the United States Army Corps of Engineers (USACE) in March of 2009, and since that time published multiple reports and updates as the study has progressed. The table below shows a summary of this progression:

Study Phase	Report Date	Description	Sub-Appendix
Phase 1	March 2009/ August 2009	Draft Report- Hydrological Analysis based on the period of record	Appendix A-1A
Phase 2a	October 2009	Expert Opinion Elicitation	Appendix A-1B
Phase 2b	February 2010	HEC Report	Appendix A-1C
Phase 3	May 2010	Hydrology Updated for Wet and Dry Cycles	Appendix A-2
Phase 3.1	July 2010	Study Area Extended	Appendix A-3
Phase 3.2	July 2010	Hydrology Amended- Fargo to Halstad	Appendix 4A & 4B
Phase 4	January 2011	Hydrological Analysis in Support of Unsteady RAS Modeling and Design	Appendix 4B

Phase 1: Period of Record Analysis. In August 2009, a report entitled "Fargo-Moorhead Metro Flood Risk Management Project, Feasibility Report" was completed. The hydrological analysis carried out for this phase of the study consists of developing the needed inputs to steady and unsteady water surface profile models (HEC-Ras) for the Red River of the North through the City of Fargo, ND. The steady flow model required synthetic events derived from a discharge-frequency analysis. The unsteady flow-model requires balanced hydrographs. Flow-frequency analysis for the Red River of the North watershed between Wahpeton, ND and Grand Forks, ND was carried out for the full period of record. Balanced hydrographs were developed in support of the unsteady flow model for selected frequency events as well as coincidental balanced hydrographs for major tributaries. Analysis was carried out for both the regulated and unregulated condition. At the time this analysis was carried 2009 flow data was still provisional.

Phase 2a: Expert Opinion Elicitation. There has been an increasing amount of evidence indicating that the flow records at the Fargo gage can no longer be considered stationary. To address this issue, the Corps project delivery team (PDT) organized an expert opinion elicitation (EOE) in September of 2009. The EOE was established to provide the PDT with specific actions that should be taken, if any, to account for the suspected non-stationarity and uncertainty associated with the flow recorded in the Fargo-Moorhead metropolitan area and assess possible future climatic change impacts. In October 2009 a report was published describing EOE recommendations. The panel concluded that the Red River peak stream flows exhibited non-stationarity in the form of two flow regimes, a wet period and a dry period, and that this result should be incorporated in development of the flow frequency curves for the Fargo Moorhead Metro Feasibility Study.

Phase 2b: HEC Analysis- WET/DRY Analysis. A contract was drafted between the St. Paul District and the Corps Hydrologic Engineering Center (HEC) to implement the recommendations of the EOE. HEC developed a methodology that could be used to generate separate flow frequency curves for the wet and dry periods. The flow record was divided into two segments based on a test to determine the break point providing the strongest statistical evidence of separate homogenous data sets. The resulting break point of 1941 defined the WET portion of the period of record as 1942-2009. The WET and DRY frequency curves were combined to reflect the likelihood of experiencing either the wet or dry flow regime in future years (25 year look ahead and 50 year look ahead).

Phase 3: Hydrology Updated for WET/DRY Cycles. In May 2010 the hydrological analysis carried out in Phase 1 was updated for the Red River reach between Hickson, ND and Grand Forks, ND. This analysis generates three frequency curves: one for the present climate condition labeled as WET, a second labeled as a combination of WET and DRY with 80% weight for WET and 20% weight for Dry, and a third frequency curve combination with a weight of 65% Wet and 35% DRY. The WET curve represents year one in the planning period transitioning to the second combination curve in 25 years and again a transition to the third combination curve at the end of the 50-yr planning period. Flow-frequency curves were updated as inputs to the steady flow model. Balanced hydrographs were updated as inputs to the unsteady flow model. Analysis was carried out for both the regulated and unregulated condition.

Phase 3.1: Study Area Extended Downstream. Initially hydraulic modeling of the Red River of the North only extended to Halstad, MN. After carrying out initial analysis, the PDT determined that the downstream impacts associated with proposed project extend beyond Halstad, MN. To try to fully define downstream impacts, analyses had to be carried further downstream and the study reach was extended to Emerson, Canada. Flow-frequency and balance hydrograph analysis was carried out downstream for the WET portion of the period of record.

Phase 3.2: Hydrology Amended- Fargo to Halstad. With the May 2010 submittal, it was noted that Phase 3 hydrology significantly increased flows through Fargo, yet the flows further downstream, at locations such as Halstad and Grand Forks did not increase significantly. Further refinement of the hydrology particularly with the Sheyenne River coincidental flows resulted in improved results. Given the important impact the Sheyenne River has on project parameters, a revision to the Phase 3 Hydrology was developed. Revisions of the Sheyenne River hydrology consisted of developing a Lower Sheyenne River model to carry out flow-frequency analysis for the Rush River, Maple River, and at points of interest in the Lower Sheyenne River Watershed for the WET portion of the period of record. Based on this frequency analysis, balanced hydrographs could then be generated at points of interest within the Lower Sheyenne River Basin. This analysis required the development of an HMS model that takes into account the effects of breakouts and regulatory structures within the Sheyenne River watershed and extending HMS routing along the Red River between Fargo and Halstad.

Phase 4: Hydrological Analysis in Support of Unsteady RAS Modeling and Design. After the downstream impacts of the project developed in earlier phases of analysis were analyzed it was determined that they were not fully definable and another approach was needed. The USACE and local project sponsors decided to pursue an option that included raising water levels, or staging, upstream of the Fargo-Moorhead Metro area. This proposal would include constructed storage areas as well as natural storage options. To develop a design that incorporates the benefits of upstream storage and staging, an unsteady flow model was required for the study area. The unsteady model requires synthetic balanced hydrographs representative of points of interest in the basin as boundary conditions. Further balanced hydrographs were developed for locations within the Lower Sheyenne River Basin as boundary conditions to the Unsteady RAS model.

Coincidental discharge frequency values and balanced hydrographs are determined for the 500-, 100-, 50, and 10-yr events for locations upstream and downstream of Fargo in order to develop design parameters for appurtenant structures on the Sheyenne, Maple and Rush River tributaries.

Analysis Results Summary. A master table summarizing the results of all flow-frequency analysis carried out to date for the Fargo-Moorhead Metro Study is displayed in the following table. This table summarizes the flows for the discharge-frequencies on the mainstem of Red River of the North. Significant tributary discharge-frequencies values are also shown in terms of coincidental flow-frequencies. Locations that have a USGS streamflow gage are shaded in green.

Summary Discharge-Frequencies; Red River

LOCATION	Drainage Area sq. mi.	DISCHARGES in cfs Recurrence Interval 2-YR	4-YR	5-YR	10-YR	20-YR	50-YR	100-YR	200-YR	500-YR	1000-yr	10000-yr	Reference Appendix	Sections	Tables
Emerson	30,030	27,937		50,461	66,690	83,572	106,697	124,815	145,463	169,069			A-3	2.1.3, 2.2	18, 20
Pembina River Coinc.	3,950	1,002		3,640	5,728	7,399	8,831	9,189	9,308	9,427			A-3	4.3.2	36, 37
U/S Pembina River, ND	26,040	26,935		46,441	60,922	76,173	97,866	115,626	134,175	159,573					
D/S Two Rivers, MN	26,010	26,968		47,227	62,294	77,991	99,976	117,693	136,156	161,428					
Two Rivers Coinc.	1,230	1,082		3,149	4,625	5,806	6,691	6,790	6,888	6,986			A-3	4.2.2	33, 34
U/S Two Rivers, MN	24,780	25,886		44,078	57,669	72,185	93,285	110,903	129,268	154,442					
Drayton	24,670	26,009		47,027	62,847	79,061	101,292	118,757	136,789	161,486			A-3	2.1.2, 2.2	17, 20
D/S Park River, ND	24,100	25,329		47,441	64,630	82,603	106,697	125,252	143,672	168,702					
Park River Coinc.	1,010	550		1,700	2,800	4,300	6,000	7,000	7,500	8,000			A-3	3.2.3	22, 26
U/S Park River, ND	23,090	24,779		45,741	61,830	78,303	100,697	118,252	136,172	160,702					
D/S Snake River, MN	23,060	24,742		45,763	61,927	78,494	100,989	118,602	136,545	161,094					
Snake River Coinc.	950	342		1,174	2,004	2,921	3,912	4,592	5,084	5,694			A-3	3.2.2	22, 24
U/S Snake River, MN	22,110	24,400		44,589	59,923	75,573	97,077	114,010	131,460	155,399					

Summary Discharge Table. Continued.

LOCATION	Drainage Area sq. mi.	DISCHARGES in cfs Recurrence Interval 2-YR	4-YR	5-YR	10-YR	20-YR	50-YR	100-YR	200-YR	500-YR	1000-yr	10000-yr	Reference Appendix	Sections	Tables
D/S Forest River, ND	22,080	24,363		44,611	60,020	75,765	97,370	114,363	131,836	155,794					
Forest River Coinc.	900	210		750	1,300	1,800	2,350	2,700	2,850	3,000			A-3	3.2.1	22, 23
U/S Forrest River, ND	21,180	24,153		43,861	58,720	73,965	95,020	111,663	128,986	152,794					
Oslo	21,105	24,056		43,920	58,970	74,459	95,773	112,569	129,950	153,811			A-3	2.1.1, 2.2	15, 20
D/S Turtle River, MN	21,105	24,056		43,920	58,970	74,459	95,773	112,569	129,950	153,811					
Turtle River Coinc.	635	547		1,282	1,885	2,524	3,422	4,132	4,867	5,868			A-3	3.1.1	21
U/S Turtle River, MN	20,319	23,509		42,638	57,086	71,935	92,351	108,437	125,083	147,943					
Grand Forks	20,015	23,295		42,139	56,354	70,956	91,026	106,838	123,201	145,675			A-3	1.1.6	9
d/s Red Lake	20,015	23,295		42,139	56,354	70,956	91,026	106,838	123,201	145,675					
Red Lake Coinc.	3,800	7,379		11,604	13,399	15,437	18,128	20,073	22,200	24,595			A-3	1.1.4, 1.1.6	7, 8, 9
u/s Red Lake	16,215	15,916		30,535	42,955	55,519	72,898	86,765	101,001	121,080					
Thompson	16,095	15,792		30,535	42,899	55,519	72,898	86,765	101,001	121,080			A-3	1.1.6	9
d/s Sand Hill River	16,015	15,709		30,535	42,862	55,519	72,898	86,765	101,001	121,080					
Sand Hill River Coinc.	430	763		1,801	2,700	3,451	4,000	4,226	4,367	4,532			A-3	1.1.3, 1.1.6	5, 6, 9
u/s Sand Hill River	15,585	14,946		28,734	40,162	52,068	68,898	82,539	96,634	116,548					

Summary Discharge Table Continued.

LOCATION	Drainage Area sq. mi.	DISCHARGES in cfs Recurrence Interval 2-YR	4-YR	5-YR	10-YR	20-YR	50-YR	100-YR	200-YR	500-YR	1000-yr	10000-yr	Appendix	Reference Sections	Tables
d/s Marsh River	15,375	14,734		28,734	40,067	52,068	68,898	82,539	96,634	116,548					
Marsh River Coinc.	150	712		1,511	2,420	3,145	3,996	4,709	5,151	5,543			A-3	1.1.2, 1.1.6	3, 4, 9
u/s Marsh River	15,225	14,022		27,223	37,648	48,923	64,902	77,830	91,484	111,005					
d/s Goose River	15,225	14,022		27,223	37,648	48,923	64,902	77,830	91,484	111,005					
Goose River Coinc.	1,160	657		1,964	2,650	3,908	5,596	7,032	8,612	11,292			A-3	1.1.1, 1.1.6	1, 2, 9
u/s Goose River	14,065	13,365		25,259	34,998	45,014	59,306	70,798	82,872	99,713					
Halstad	13,775	13,074	22,261	25,260	34,871	45,014	59,306	70,798	82,872	99,713	113,103	162,000	A-3	1.1.6	9
d/s Wild Rice, MN	13,735	13,051	22,232	25,229	34,830	44,962	59,238	70,715	82,794	99,638	113,028	161,928			
Wild Rice River, MN coinc.	1,650	2,348	4,089	4,647	6,393	8,165	10,547	12,450	12,600	12,950	13,200	13,700	A-2	5.3, 5.3.3	19, 22
u/s Wild Rice, MN	12,085	10,703	18,143	20,582	28,437	36,797	48,691	58,265	70,194	86,688	99,828	148,228			
d/s Elm	12,055	10,687	18,123	20,560	28,409	36,761	48,644	58,206	70,138	86,632	99,771	148,172			
u/s Elm	11,655	10,472	17,854	20,267	28,028	36,271	48,004	57,418	69,381	85,876	99,006	147,414			
d/s Buffalo	11,305	10,282	17,614	20,006	27,688	35,834	47,433	56,714	68,704	85,199	98,319	146,733			
Buffalo River coinc.	1,190	1,312	2,615	3,061	4,431	5,809	7,604	9,100	9,275	9,600	9,850	10,450	A-2	5.3, 5.3.2	19, 20, 21
U/S Buffalo	10,115	8,970	14,999	16,945	23,257	30,025	39,829	47,614	59,429	75,599	88,469	136,283			

Summary Discharge Table Continued.

LOCATION	Drainage Area sq. mi.	DISCHARGES in cfs Recurrence Interval 2-YR	4-YR	5-YR	10-YR	20-YR	50-YR	100-YR	200-YR	500-YR	1000-yr	10000-yr	Appendix	Reference Sections	Tables
d/s Sheyenne	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
Sheyenne River coinc.	4,850	2,949	3,834	4,177	5,446	6,985	9,163	11,242	11,488	12,048	12,530	13,203	A-2	6.3.2	32, 33, 34
u/s Sheyenne	5,055	5,908	11,026	12,618	17,616	22,791	30,340	35,970	47,541	63,141	75,517	122,646			
Fargo	4,625[1] 3,220[2]	5,600	10,600	12,150	17,000	22,000	29,300	34,700	46,200	61,700	74,000	121,000	A-2	5.1.2	7 - 12
d/s Drain 53	3,165	5,564		12,022	16,844	21,810	29,058	34,398	45,774	61,099					
Drain 53 coincidental	30	26		70	113	158	213	252	289	336					
u/s Drain 53	3,135	5,538		11,952	16,731	21,652	28,845	34,146	45,485	60,763					
d/s Wild Rice	3,080	5,508		11,823	16,600	21,514	28,679	33,927	45,110	60,160					
Wild Rice River coin @ ABER	1,640	1,419	2,587	3,021	6,185	8,648	11,655	13,780	15,801	18,342			A-2	5.2, 5.3, 5.3.1	17, 18, 19
u/s Wild Rice	1,440	4,089		8,802	10,415	12,866	17,024	20,147	29,309	41,818					
d/s Wolverton	1,430	4,133		7,386	11,005	14,630	19,819	22,999	29,874	38,891					
Wolverton coincidental	105	91	210	250	396	554	746	882	1,012	1,174					
u/s Wolverton	1,325	4,042		7,136	10,609	14,077	19,073	22,117	28,862	37,716					
Hickson	1,310	4,000		7,000	10,500	14,000	19,000	22,000	28,500	37,000			A-2	5.1.2, 5.1.4	7 - 9, 14

[1]4,625 sq. mi. is the total contributing drainage area upstream of Fargo including the area upstream of the dams. This was used in interpolating flows between Fargo and Emerson.
[2]3,220 sq. mi. is the incremental local contributing area between Fargo and the upstream dams. This was used in interpolating flows between Hickson and Fargo.

Appendix A-1a
Hydrology

Fargo-Moorhead Metropolitan Area
Flood Risk Management

Supplemental Draft Feasibility Report
and Environmental Impact Statement

April 2011

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1.0 OBJECTIVE AND STUDY LIMITS

The objective of this study is to develop the hydrology needed as input to a steady and unsteady water surface profile model (HEC-RAS) for the Red River of the North through the City of Fargo, ND. The steady flow model required synthetic events derived from a discharge-frequency analysis. These events were the 50%, 20%, 10%, 5%, 2%, 1%, 0.5%, and 0.2% events. The unsteady flow model required balanced hydrographs for the 10%, 2%, 1%, and 0.2% events.

The hydraulic study reach extends from the downstream end at the Halstad gage to the upstream end at the Wahpeton gage. A Red River main stem discharge-frequency analysis was done to determine a consistent set of discharge-frequency curves along the Red River. The hydrologic study extended downstream to Grand Forks because it is the long-term station on the Red River. Balanced hydrographs were developed for the unsteady flow model for selected frequency events as well as coincidental Balanced Hydrographs for the major tributaries.

The Sheyenne River was also included as part of the study limits. The unsteady flow model extended from the confluence with the Red River to upstream at the West Fargo gage. Therefore, coincidental balanced hydrographs were also developed for this reach.

Figure 1 and Figure 2 show the Red River of the North from Halstad, ND to the upstream reservoirs on the Bois de Sioux and Otter Tail Rivers. **Figure 3 and Figure 4** show how model schematics of the study reach. Discharge-frequency analyses were done in accordance with Bulletin 17B (**reference 1**).

2.0 DESCRIPTION OF WATERSHED

2.1 RED RIVER OF THE NORTH

The upper end of the Red River of the North is formed within the communities of Wahpeton, North Dakota and Breckenridge, Minnesota by the confluence of the Bois de Sioux and the Otter Tail rivers. The total drainage area above this combining point is 4,010 square miles of which 1,585 square miles are considered noncontributing. The noncontributing drainage area is that area which does not contribute to flow, and is similar to the term "closed area" as used by the U.S. Geological Survey. The remaining 2,425 square miles are contributing drainage of which 1,020 square miles are considered to be the local effective drainage area downstream of two flood control reservoirs, White Rock Dam at the outlet of the Lake Traverse Reservoir Project and Orwell Dam on the Otter Tail River. The contributing drainage areas are 1,160 square miles to White Rock Dam and 245 square miles to Orwell Dam. Lake Traverse/White Rock Dam went into operation in 1942. Orwell Dam went into operation in 1953. **Figure 5** shows a drainage area schematic for a Hec-5 model that was developed for this study and **Table 1** and **Table 2** list the contributing drainage areas used in this analysis.

These drainage areas are divided into primary, secondary and non-contributing drainage areas defined as follows:

A. Primary contributing drainage area is that area which has a direct watercourse to the main stem of the river.
B. Secondary contribution drainage area is the area which begins to contribute during floods greater than the 2% chance of exceedance flood. Secondary contribution area is assumed to be enclosed by a 5-foot contour line on a 7.5 minute USGS topographical map.
C. Non-contribution drainage area is that area which does not contribute to flow. Non-contributing areas are assumed to be enclosed by a 10-foot or more contour line on the 7.5 minute topographical maps.

Table 1-Red River Contributing Drainage Areas.

Location	Trbutary D.A	Contributing D.A Below Dams	Total Contributing D.A incl. Above Dams
		Square Miles	
Halstad		13,775	
d/s Wild Rice		13,735	
Wild Rice River, MN	1,650		
u/s Wild Rice		12,085	
d/s Elm		12,055	
Elm River	400		
u/s Elm		11,655	
d/s Buffalo R		11,305	
Buffalo River	1,190		
u/s Buffalo R		10,115	
d/s Sheyenne	4,850	9,905	
Sheyenne River			
u/s Sheyenne		5,055	
Fargo		3,220	4,625
d/s Drain 53		3,165	4,570
Drain 53	30		
u/s Drain 53		3,135	4,540
D/S Wild Rice River		3,080	4,485
Wild Rice River, ND	1,640		
U/S Wild Rice River		1,440	2,845
D/S Wolverton		1,430	2,835
Wolverton Creek	105		
U/S Wolverton		1,325	2,730
Hickson		1,310	2,715
Wahpeton		1,020	2,425

Table 2- Drainage Areas above Fargo

River	Location	Drainage Area , sq. mi.			
		Primary	Secondary	Non-contributing	Total
Bois de Sioux					
	White Rock Dam	1,160			1,160
	Local areas between White Rock and Wahpeton	807			807
	Above confluence with Ottertail River	1,967			1,967
Ottertail					
	Above Orwell	245		1,585	1,830
	Local area between Orwell & Wahpeton	213		1,585	2,043
	Mouth (Wahpeton)	458			213
Red River of the North					
	USGS Gage @ Wahpeton	2,425		1,585	4,010
	Hickson	2,715		1,585	4,300
Wild Rice					
	Near Mantador	687	120	550	1,357
	CSAH 13 near Wahpeton	895	120	590	1,605
	Abercrombie	1,370	120	590	2,080
Red River					
	Local area between Hickson, Abercrombie, & Fargo	420			420
	Fargo	4,505	120	2,175	6,800

2.2 BOIS DE SIOUX RIVER

The Bois de Sioux River forms the eastern boundary of Wahpeton and the western boundary of Breckenridge. It is also the state boundary between North Dakota and Minnesota. The river follows a meandering course northward from White Rock Dam at Lake Traverse until it reaches the confluence with the Otter Tail River at Wahpeton, where together they form the Red River of the North.

The watershed drained by the Bois de Sioux River lies within the former bed of Glacial Lake Agassiz. As a result, most of the Bois de Sioux River watershed is a flat lowland glacial plain, with the exception of the upland western portion, which is gently rolling glacial plain. The transition zone between the upland and lowland plains is composed of former beach ridges with moderate slopes.

The total drainage area of the Bois de Sioux River above the confluence with the Otter Tail River is 1,967 square miles with the local contributing drainage area below White Rock Dam being 807 square miles. The upper reach of the Bois de Sioux is regulated by White Rock Dam at the outlet of the Lake Traverse Reservoir Project and controls runoff from 1,160 square miles of contributing drainage area. The Bois de Sioux River has an average channel slope of approximately 0.3 feet per mile between White Rock Dam and Wahpeton/Breckenridge.

White Rock Dam is operated for a target stage at Wahpeton. If the target stage at Wahpeton is in danger of being exceeded releases from the reservoir are reduced to zero until the reservoir elevation peaks and begins to fall. If the water level in Lake Traverse/ Mud Lake reaches the full pool elevation of 981.0 feet, the gates at White Rock Dam are raised clear of the water surface until the pool again falls below elevation 981.0.

A review of reservoir release records indicated that, with the exception of 1997, 2001, and 2009, operation of White Rock Dam allowed for minimal releases during the period of the annual peak flow at Wahpeton/Breckenridge. Therefore, with the exception of floods that cause the reservoir pool elevation to climb near El. 981 (~ 0.05 exceedance probability- USACE Water Control Manual Stage-Frequency Relationship), the major contributing drainage from the Bois de Sioux River basin is the local drainage area of 807 square miles when the reservoir is being operated for the critical stage at Wahpeton.

Breakout flows from the Bois de Sioux River to the Wild Rice River in North Dakota occur during high flow conditions. For flood events on the Bois de Sioux River that have a return period equal to about 5 years, flow begins to back up County Ditch No. 55 at North Dakota State Highway 127 at an approximate location 3 miles south of the Wahpeton corporate limits. For larger flood events on the Bois de Sioux River (like that experienced in 2009 and1997), flood waters start to flow over State Highway 127 about one-half mile south of the Wahpeton airport. These breakout flows continue to the northwest and eventually reach the Wild Rice River, which flows generally north to where it joins the Red River of the North upstream of Fargo, North Dakota. A schematic of this process can be seen in **Figure 6**. The analysis presented in this report includes the impacts from breakout flows for these larger flood events and assumes the existing breakout flow geometry will continue to exist in the future.

2.3 OTTER TAIL RIVER

The Otter Tail River rises west of Fergus Falls, Minnesota and flows south through a series of lakes until it reaches Otter Tail Lake, where it turns and flows west to its confluence with the Bois de Sioux River at Wahpeton/Breckenridge. The basin, which lies within the former bed of Glacial Lake Agassiz, contains more than 1,100 lakes, covering more than 15 percent of the total basin area. An additional 6 percent of the basin area is comprised of swamps and marshes.

The total drainage area of the Otter Tail River is 2,043 square miles of which 1,585 square miles are considered to be noncontributing. The local contributing drainage area below Orwell Dam is 213 square miles. The upper portion of the Otter Tail River basin is regulated by Orwell Dam and controls runoff from a contributing drainage of 245 square miles. The average slope of the Otter Tail River from Orwell Dam to Breckenridge is 3.0 feet per mile. Similar in operation to White Rock Dam, Orwell Dam is regulated to allow minimal releases during periods of high flow at Wahpeton/Breckenridge. However, because of its limited storage capacity of about 13,000 acre-feet, outflows from Orwell Dam impact peak flows at Wahpeton/Breckenridge on a more frequent basis than those from White Rock Dam.

2.4 SHEYENNE RIVER

Figure 2 shows the drainage areas above the mouth of the Sheyenne River in North Dakota. The Maple, Rush, and Lower Rush Rivers are tributary to the Sheyenne River and have their confluence near the confluence of the Sheyenne River and Red River of the North. The drainage areas of the Sheyenne, Maple, Rush, and Lower Rush Rivers are 6,900, 1,518, 172, and 66 square miles, respectively. Flow on the Sheyenne River is regulated by Baldhill Dam above Valley City, ND. **Figure 7** shows the major drainage area subdivided at pertinent locations. For the Sheyenne River Basin, the subdivide is at the USGS gaging station on the Sheyenne River above the inlet structure for the Horace diversion near Horace. The Maple Basin is subdivided at the USGS gaging station at Enderlin, ND and the Rush River Basin is subdivided at the USGS gaging station near Amenia, ND. The drainage area above Enderlin and Amenia is 843 and 116 square miles respectively. Of the 843 square miles above Enderlin, the USGS lists 796 square miles as contributing.

There are two USGS gages in the vicinity of West Fargo. One gage is on the West Fargo Diversion at I-29 (05059480) and the other is on the old Sheyenne River channel (05059500). **Figure 8** shows the location of these gages. The USGS lists the contributing drainage area at the latter gage as 3,090 square miles. Based on this the contributing drainage area of the Sheyenne River at the mouth is estimated to be 4,625 sq. miles. This includes the 172 sq. mi. for the Rush River, 1,518 sq. mi. for the Maple, and 66 sq. mi. for the Lower Rush Rivers.

Harwood, ND is located adjacent to the Sheyenne River and is situated below the confluence with the Maple river but immediately upstream of the confluence with the Rush and Lower Rush Rivers. As a result, this river reach experiences backwater effects from the Red River as well as the Rush and Lower Rush Rivers.

The West Fargo and Horace Levee and Diversion projects are located on the lower portion of the Sheyenne River and extend from near Horace through the City of West Fargo, ND. The Maple River confluence and the City of Harwood, ND are downstream from the project. The diversion project was completed in 1992 **Table 3** lists the contributing drainage areas on the Lower Sheyenne River basin used in this study.

Table 3- Contributing Drainage Area – Sheyenne River.

Location	Tributary	Contributing Area Below Dams
	sq. mi.	sq.mi
West Fargo USGS gage		3,090
Shey R. U/S of Maple R.		3,092
Maple River	1,518	
Shey R. D/S of Maple R.		4,610
Shey R. U/S of Rush R.		4,611
Rush & L. Rush R.	238	
Shey R. D/S of Rush R.		4,849
Sheyenne confluence		4,859

2.5 STREAM GAGES

The U.S. Geological Survey (U.S.G.S.) maintains several continuous streamflow recording gages along the Red River of the North. Gaged streamflow data used for this study included stations located on the Red River at Grand Forks (USGS gage No. 05082500), the Red River at Halstad (USGS gage No.05064500), Red River at Fargo, ND (USGS gage No. 05054000) and the Red River at Wahpeton, ND (USGS gage No. 05051500). Limited streamflow records are also available for the Bois de Sioux River near Doran, Minnesota (USGS gage No. 05051300). Outflows from White Rock Dam and Orwell Dam are also gaged by the USGS. **Figure 9** shows a schematic of the stations and years of record for peak streamflow. Tributary gages on the Wild Rice, ND, Wild Rice, MN, and Buffalo River are also included. **Table 4** lists peaks for the 2009 flood event for selected stations along with historical data for comparison.

Table 4- Maximum Peaks – Period of Record and from March to May 2009

[illegible]	[illegible]	[illegible]	[illegible]							
			POR Prior to 2009 Event				March to May 2009			
			Date	Stage (ft)	Date	Discharge (cfs)	Date	Stage (ft)	Date	Discharge (cfs)
[illegible]	4,010	1897	1897	17.00	1897	10,500	3/24/2009	17.5	3/24/2009	[illegible]
		1943-2009	4/?/1997	19.42	na	na				
			4/?/1997	19.23	4/?/1997	12,800				
			4/3/2006	20.4	4/3/2006	14,400				
[illegible]	4,300	1979-2009	4/11/1989	35.81	4/11/1989	12,900	3/26/2009	38.07	3/28/2009	23,700
			4/14/1997	38.35	4/14/1997	15,300				
			4/16/1997	37.4	4/16/1997	12,900				
[illegible]	2,090	1897	1897	27.50	na	na	3/28/2009	27.77	3/28/2009	14,700
		1953-2008	4/11/1969	24.58	4/11/1969	9,540				
			4/6/1997	26.59	na	na				
			4/18/1997	25.40	4/18/1997	9,470				
[illegible]	6,800	1882	4/7/1897	38.10	4/7/1897	25,000	3/28/2009	40.82	3/28/2009	29,500
		1997	4/17/1997	39.54	4/17/1997	26,000				
		1903-2001	4/18/1997	39.72	4/18/1997	27,700				
[illegible]	454	1945-2009	7/2/1975	19.80	7/2/1975	8,500	3/25/2009	18.02	3/25/2009	7,250
[illegible]	21,800	1936-1937	4/22/1979	38.00	4/22/1979	42,000	3/30/2009	40.83	3/30/2009	57,400
		1942-2009	4/?/1997	45.41	4/?/1997	71,500				
[illegible]	30,100	1882-2009	4/18/1997	50.20	4/18/1997	85,000	4/1/2009	49.49	4/1/2009	78,700
			4/18/1997	52.21	4/18/1997	137,000				
			4/22/1997	54.35	4/22/1997	114,000				

g [illegible]

NOTES

a Affected by regulation period

b Backwater from aquatic vegetation, Ice debris, or other water resource

c From floodmark/high

d Extreme outside period of record

e About 2,200 cubic ft/s of overland flow entered the Wild River Basin about 7 miles

f Maximum observed, flow affected by breakout flow from Red River about 20 river miles upstream of gage that entered the Red Lake River

na not available at this time

2.5.1 Grand Forks

The continuous streamflow recording station for the Red River of the North at Grand Forks is located 0.4 mile downstream from the Red Lake River at mile 293.8 and drains a total area of 30,100 square miles of which 8,655 square miles are considered noncontributing. The gage location and datum has changed numerous times during the 128 years of continuous existence and currently has a datum of 779.00 feet above sea level. The period of record dates back to April 1882 with historic flood information available for 1826, 1852 and 1861. For the period of 1904 to 2009, the mean monthly flow varies from as little as 900 cfs in February to as high as 10,900 cfs in April. The largest recorded discharge occurred on April 18, 1997 and had an instantaneous peak of 136,900 cfs with a stage of 52.21 feet. The maximum stage of record of 54.35 feet occurred 4 days later on April 22, 1997 with an instantaneous peak discharge of 114,000 cfs.

The historic floods of 1826, 1852 and 1861 are documented in letters and journals with specific information regarding maximum water levels and flood durations. Prior studies have estimated Red River discharges downstream of the Assiniboine River at Winnipeg, Manitoba for the 1826, 1852 and 1861 floods to be 225,000 cfs, 165,000 cfs and 125,000 cfs, respectively. Further analyses utilized linear regression and drainage area - discharge relationships to transfer historical flood values from the Red River of the North at Winnipeg to Emerson, North Dakota and Grand Forks. The resulting peak discharges at Grand Forks were determined to be 135,000 cfs for 1826, 95,000 cfs for 1852 and 65,000 cfs for 1861. The available literature leaves no doubt that large floods occurred during these years. The referenced previous studies concluded that the analyses yielded reasonable results for development of historic flood data at Grand Forks.

2.5.2 Fargo, Red River

The U.S. Geological Survey streamflow gage for the Red River of the North at Fargo is located at the water treatment plant on 4th Street South, at river mile 453, approximately 25 miles upstream of the mouth of the Sheyenne River. The total drainage area at this gage is 6,800 square miles of which 2,175 square miles are considered noncontributing. Of the remaining 4,625 square miles, 1,405 square miles are controlled by White Rock Dam and Orwell Dam. The gage location and datum has changed several times during the 109 years of continuous existence and currently has a datum of elevation 861.8 feet above sea level. The continuous period of record dates back to May 1901, with historic flood information available for 1882 and 1897.

The largest observed flow occurred on 28 March 2009 and had an estimated instantaneous peak discharge of 29,400 cfs. This was approximately a 100-yr event. Cold temperatures during the rising limb of the flood hydrograph arrested the runoff process and stemmed what would likely have been a 200-yr event as experienced just upstream at Hickson and Wahpeton. The second highest flood of record occurred on 17 April 1997 with an instantaneous peak discharge of 29,000 cfs.

Historic flood information indicates peak discharges of 20,000 cfs occurred on April 11, 1882 and 25,000 cfs occurred on April 7, 1897. **Table 5** lists the recorded instantaneous peaks flows at Fargo.

2.5.3 Hickson, Red River

Six miles upstream of the confluence of the Wild Rice River, ND, on the Red River is located the Hickson USGS (05051522) gage. This station has a short-term record from 1976 to present. The largest flood of record also occurred in 2009 on 26 March with a mean daily peak discharge of 22,500 cfs. This is approximately a 200-yr event. **Table 6** lists the instantaneous peak discharges.

2.5.4 Wahpeton, Red River

The continuous streamflow recording station for the Red River of the North at Wahpeton is located 800 feet downstream from the confluence of the Bois de Sioux River and the Otter Tail River at river mile 548.6. The current gage datum is 942.97 feet above sea level. The period of record dates back to April 1942, with observed flow measurements that are considered fair. Historic information for the spring flood of 1897 indicates a maximum stage of 17.0 feet with an estimated discharge of 10,500 cfs. If White Rock Dam (constructed in 1942) had been in place in 1897, the subsequent peak discharge would have likely been reduced. The largest recorded discharge occurred on 24 March 2009. The USGS estimated a provisional mean daily peak discharge of 15,400 cfs and does not include breakout flow that occurred on the Bois de Sioux upstream of the gaging station. This flow includes flow for the diversion that bypasses the City of Breckenridge, MN. This study estimated the instantaneous peak at approximately 15,560 cfs which includes flow through the Breckenridge Diversion. Upstream breakout flow was estimated to be approximately 4,040 cfs using the relationship presented later in this report. Total discharge at Wahpeton was estimated to be 19,600 cfs including the estimated flow that broke out.

The second largest event occurred on 15 April 1997 and had an instantaneous peak discharge of 12,800 cfs and does not include breakout flow estimated at 2,220 cfs. The instantaneous peak stage of 19.42 feet occurred on April 6 and was influenced by backwater from ice. **Table 7** lists the recorded instantaneous peak flows at Wahpeton.

2.5.5 Abercrombie, Wild Rice River, ND

The Abercrombie gage(USGS 05053000) on the Wild Rice River is located just upstream of the confluence with the Red River near the town of Abercrombie. It has 77 years of record and gages streamflow from 2,080 square miles of which 1,490 is contributing area. This gage was used to estimate coincident flow corresponding to peak flow on the Red River.

2.5.6 Doran, Bois de Sioux River

The continuous streamflow recording station for the Bois de Sioux River near Doran is located 6.3 miles downstream of the Rabbit River and approximately 10 miles upstream of the Otter Tail River and is also upstream of the County Ditch No. 55 and State Highway 127 breakout flow area. The current gage datum is 943.90 feet above sea level. The period of record dates back only to October of 1989 with observed flow measurements that are considered to be good. The largest recorded instantaneous peak discharge was 12,300 cfs on April 16, 1997 with the highest recorded instantaneous peak stage of 24.42 feet occurring on the same day. The total drainage area is 1,880 square miles with the primary drainage area considered to be 720 square miles (1,160 square miles above White Rock Dam).

Table 5 -Fargo Gage Peak Flows.

Cass County, North Dakota
Hydrologic Unit Code 09020104
Latitude 46°51'40", Longitude 96°47'00" NAD27
Drainage area 6,800 square miles
Gage datum 861.8 feet above sea level NGVD29

Water Year	Gage Height (feet)	Stream-flow (cfs)	Water Year	Gage Height (feet)	Stream-flow (cfs)	Water Year	Gage Height (feet)	Stream-flow (cfs)
1897	39.10[3]	25,000[7]	1937	10.17	1,390	1974	20.25	4,150[6]
1902	10.50	1,180[1]	1938	10.02	1,350	1975	33.26	13,200[6]
1903	13.90	2,450[1]	1939	13.00	3,870	1976	18.70	3,200[6]
1904	21.30	5,220[1]	1940	9.63	1,030	1977	14.99	878[6]
1905	18.40	4,250[1]	1941	10.10	1,390	1978	34.41	17,500[6]
1906	15.50	3,050[1]	1942	12.27	3,380[6]	1979	34.93	17,300[6]
1907	29.80	7,000[1]	1943	28.40	16,000[6]	1980	20.74	5,470[6]
1908	14.70	2,600[1]	1944	14.26	4,150[6]	1981	15.84	1,710[6]
1909	12.50[2]	1,780[1]	1945	20.70	7,700[6]	1982	25.07[1]	5,920[6]
1910	23.10	5,000[1,2]	1946	17.13	5,970[6]	1983	15.99	1,750[6]
1911	8.70	608[1]	1947	22.93	9,300[6]	1984	28.27	9,550[6]
1912	10.60	1,100[1]	1948	12.45	3,390[6]	1985	20.08	4,690[6]
1913	11.90	1,560[1]	1949	11.27	2,660[6]	1986	27.19	8,640[6]
1914	16.10	3,140	1950	20.88	7,800[6]	1987	17.75	3,300[6]
1915	9.73	3,130	1951	20.73	8,010[6]	1988	15.10	981[6]
1916	[2]	7,740	1952	28.79	16,300[6]	1989	35.39	18,900[6]
1917	17.80[1]	5,240	1953	18.05	6,720[6]	1990	15.40	1,220[6]
1918	6.87	874	1954	10.53	1,920[6]	1991	16.99	2,630[6]
1919	6.50	680	1955	11.12	2,760[6]	1992	16.93	2,590[1,6]
1920	17.20	6,200	1956	12.54	3,870[6]	1993	28.27	10,100[6]
1921	8.40	1,970	1957	11.10	2,540[6]	1994	26.69	11,200[6]
1922	14.70	5,200	1958	10.90	2,280[6]	1995	28.37	11,000[6]
1923	11.60	3,960	1959	10.42	1,250[6]	1996	28.75	9,940[6]
1924	6.20	530	1960	12.48[1]	3,900[6]	1997	39.57[2]	28,000[6]
1925	7.00	940	1961	9.24	1,020[6]	1998	24.87	8,610[6]
1926	8.00	1,600	1962	22.83	9,580[6]	1999	20.81[1]	4,900[2,6]
1927	9.10	2,650	1963	19.97	4,930[6]	2000	22.20[2]	5,630[6]
1928	13.30[1]	3,840	1964	16.22	2,400[6]	2001	36.69	20,300[6]
1929	12.80	4,440	1965	30.50	11,400[6]	2002	[2]	4,250[6]
1930	10.00	1,340	1966	30.16	10,700[6]	2003	22.63	6,710[6]
1931	8.55	365	1967	22.34	5,900[6]	2004	20.47	5,430[6]
1932	9.45	875	1968	14.71[2]	788[6]	2005	28.18	9,810[6]
1933	9.04	605	1969	37.34	25,300[6]	2006	37.13	19,900[6]
1934	8.55	323	1970	16.27	2,480[6]	2007	30.84[2]	13,500[6]
1935	9.72	942	1971	15.87	1,910[6]	2008	19.50[2]	4,840[6]
1936	9.90	1,050	1972	25.36	7,250[6]	2009	40.84	29,500[6]
			1973	16.41[1]	1,950[6]			

Stage Qualification Codes: 1 -- Gage height affected by backwater, 2 -- Gage height not the annual max
Streamflow Qualification Codes: 1 -- Discharge is a Maximum Daily Average , 2 -- Discharge is an Estimate, 6 -- Discharge affected by Regulation or Diversion, 7 -- Discharge is an Historic Peak

Table 6-Hickson Gage Peak Flows.

Cass County, North Dakota
Hydrologic Unit Code 09020104
Latitude 46°39'35", Longitude 96°47'44" NAD27
Drainage area 4,300 square miles
Gage datum 877.06 feet above sea level NGVD29

Water Year	Date	Gage Height (feet)	Stream-flow (cfs)	Water Year	Date	Gage Height (feet)	Stream-flow (cfs)
1976	Mar. 31, 1976	16.94[1]	2,500[6]	1992	Mar. 10, 1992	13.62[1]	1,750[2,6]
1977	Jun. 27, 1977	10.30	408[6]	1993	Apr. 03, 1993	28.30	6,400[6]
1978	Apr. 02, 1978	33.54	9,200[6]	1994	Apr. 01, 1994	26.43	6,320[6]
1979	Apr. 18, 1979	33.03	9,600[6]	1995	Mar. 20, 1995	29.63	8,000[6]
1980	Apr. 04, 1980	19.13	3,250[6]	1996	Apr. 14, 1996	28.26[1]	6,290[6]
1981	Aug. 04, 1981	10.41	544[6]	1997	Apr. 14, 1997	36.78[2]	13,300[6]
1982	Apr. 04, 1982	23.07[1]	4,200[6]	1998	Feb. 28, 1998	21.06	4,590[6]
1983	Mar. 19, 1983	11.08	824[6]	1999	Jun. 09, 1999	18.52[2]	3,700[6]
1984	Mar. 31, 1984	25.58[1]	5,100[6]	2000	Mar. 11, 2000	15.65[2]	2,750[6]
1985	Jun. 03, 1985	18.71	3,680[6]	2001	Apr. 12, 2001	35.30[2]	11,500[6]
1986	Apr. 01, 1986	27.27	6,720[6]	2002	Jul. 14, 2002	18.75	3,780[6]
1987	Mar. 26, 1987	15.34[1]	2,460[6]	2003	Jun. 29, 2003	20.69	4,390[6]
1988	Mar. 30, 1988	10.97	826[6]	2004	Sep. 27, 2004	16.46[2]	3,140[6]
1989	Apr. 07, 1989	35.81	12,900[6]	2005	Jun. 16, 2005	28.29[2]	7,090[6]
1990	Apr. 02, 1990	11.26	857[6]	2006	Apr. 03, 2006	36.40	14,400[6]
1991	Jul. 05, 1991	16.15	2,820[6]	2007	Jun. 07, 2007	32.08	9,410[6]
				2008	May 04, 2008	19.55	3,910[6]
				2009	Mar. 26, 2009	39.04	23,700[6]

Stage Qualification Codes: 1 -- Gage height affected by backwater, 2 -- Gage height not the annual max
Streamflow Qualification Codes: 1 -- Discharge is a Maximum Daily Average , 2 -- Discharge is an Estimate, 6 -- Discharge affected by Regulation or Diversion, 7 -- Discharge is an Historic Peak

Table 7-Wahpeton Gage Peak Flows

Richland County, North Dakota
Hydrologic Unit Code 09020104
Latitude 46°15'58", Longitude 96°35'54" NAD27
Drainage area 4,010 square miles
Gage datum 942.97 feet above sea level NGVD29

Water Year	Date	Gage Height (feet)	Stream-flow (cfs)	Water Year	Date	Gage Height (feet)	Stream-flow (cfs)
1897	1897	17.00	10,500[7,B]	1975	Jul. 03, 1975	10.84	3,850[6]
1942	Jun. 07, 1942	10.49	3,280[6]	1976	Mar. 26, 1976	9.00[1]	2,700[6]
1943	Apr. 02, 1943	14.75[1]	5,000[1,6]	1977	Jun. 25, 1977	4.49	526[6]
1944	Jun. 06, 1944	12.11	4,360[6]	1978	Mar. 31, 1978	14.04[1,2]	6,250[6]
1945	Mar. 17, 1945	11.44	3,910[6]	1979	Apr. 14, 1979	15.44[1]	7,050[6]
1946	Mar. 22, 1946	9.74	3,110[6]	1980	Apr. 01, 1980	10.71[1]	3,100[6]
1947	Apr. 12, 1947	11.90	4,610[6]	1981	Aug. 02, 1981	4.54	512[6]
1948	Apr. 06, 1948	8.58[1]	2,300[6]	1982	Apr. 01, 1982	12.26[1]	3,120[6]
1949	Jul. 10, 1949	9.24	2,290[6]	1983	Mar. 13, 1983	5.70[1]	880[6]
1950	Apr. 02, 1950	11.62	4,190[6]	1984	Mar. 28, 1984	13.43[1]	4,710[6]
1951	Apr. 07, 1951	14.01	6,090[6]	1985	Jun. 01, 1985	10.71	3,690[6]
1952	Apr. 12, 1952	14.99	7,130[6]	1986	Mar. 30, 1986	14.31	6,140[6]
1953	Jun. 21, 1953	9.87	3,150[6]	1987	Oct. 01, 1986	7.46[2]	1,770[6]
1954	Jun. 09, 1954	7.59	1,860[6]	1988	Mar. 27, 1988	5.58[1]	911[6]
1955	Apr. 02, 1955	6.99[1]	1,150[6]	1989	Apr. 05, 1989	17.95[1]	8,370[6]
1956	Apr. 14, 1956	7.88	1,980[6]	1990	Mar. 18, 1990	5.72[1]	900[2,6]
1957	Apr. 22, 1957	8.82	2,290[6]	1991	Jul. 03, 1991	9.52	2,980[6]
1958	Apr. 15, 1958	5.59	866[6]	1992	Mar. 08, 1992	8.46[1]	2,000[2,6]
1959	May 27, 1959	6.17	1,050[6]	1993	Mar. 31, 1993	14.33	6,080[6]
1960	Apr. 07, 1960	8.89[1]	2,370[6]	1994	Mar. 23, 1994	13.59[1]	5,000[2,6]
1961	Jun. 08, 1961	4.72	548[6]	1995	Mar. 17, 1995	14.88	6,370[6]
1962	Jun. 11, 1962	13.98	5,650[6]	1996	May 19, 1996	12.55[2]	5,400[6]
1963	Jun. 11, 1963	11.38	3,830[6]	1997	Apr. 15, 1997	19.25[2]	12,800[6]
1964	May 06, 1964	7.39	1,700[6]	1998	Jun. 29, 1998	11.06	4,250[6]
1965	Apr. 11, 1965	14.34	5,690[6]	1999	Jun. 07, 1999	11.02	4,220[6]
1966	Mar. 18, 1966	12.91[1,2]	4,760[6]	2000	Mar. 09, 2000	8.97[2]	2,630[6]
1967	Jun. 15, 1967	8.81[2]	2,500[6]	2001	Apr. 09, 2001	16.94	9,340[6]
1968	May 18, 1968	4.95[2]	708[6]	2002	Jul. 12, 2002	10.09	3,350[6]
1969	Apr. 10, 1969	16.34	9,200[6]	2003	Jun. 26, 2003	10.72	3,800[6]
1970	Apr. 08, 1970	6.93[1]	1,450[6]	2004	Sep. 25, 2004	10.03	3,160[6]
1971	Mar. 18, 1971	6.74[1]	927[6]	2005	Jun. 15, 2005	13.10	5,410[6]
1972	Mar. 19, 1972	11.67[1]	3,380[6]	2006	Apr. 01, 2006	15.93	7,180[6]
1973	Mar. 15, 1973	6.08[2]	1,220[6]	2007	Jun. 03, 2007	15.60	7,080[6]
1974	May 24, 1974	6.14[2]	1,250[6]	2008	Jun. 08, 2008	9.93	3,190[6]
				2009	Mar. 24, 2009	17.50	10,400[6]

Stage Qualification Codes: 1 -- Gage height affected by backwater, 2 -- Gage height not the annual max
Streamflow Qualification Codes: 1 -- Discharge is a Maximum Daily Average , 2 -- Discharge is an Estimate, 6 -- Discharge affected by Regulation or Diversion, 7 -- Discharge is an Historic Peak , B -- Month or Day of occurrence is unknown or not exact

2.6 NOMENCLATURE

Evaluation of the flow characteristics for the Red River at Fargo can be categorized in terms of two conditions. One is with Lake Traverse (White Rock) dam and Orwell dam in place. Within Appendix A-1 this condition is referred to as the "regulated" condition. Within Appendices A-2 through A-4 the "regulated" condition is sometimes referred to as the "With dams" condition. Assume that the terms "regulated" and "With dams" are interchangeable and are both indicative of the condition where the flows are affected by the Lake Traverse Project and Orwell Dam.

The other condition is without these dams in place. Within Appendix A-1 this condition this is referred to as the "natural" condition. Within Appendices A-2 through A-4 the "natural" designation" is sometimes referred to as the "unregulated" condition or the "without dams" condition. Assume that the terms "natural", "unregulated", or "without dams" are interchangeable and are all indicative of the condition where the effects of the Lake Traverse project and Orwell Dam on flows have been removed.

3. REGULATORY EFFECTS

3.1 RESEVOIR BACKGROUND INFORMATION

3.1.1 White Rock Dam/ Lake Traverse

The Lake Traverse Flood Control Project is on the boundaries of Minnesota, North Dakota, and South Dakota, 6 miles South of Wahpeton, North Dakota, and Breckenridge, Minnesota. Lake Traverse forms the headwaters of the Bois de Sioux River, which constitutes the southern limit of the Red River of the North watershed. The drainage area associated with the reservoir can be found in **Table 8**. The Lake Traverse Project consists of: the Browns Valley Dike, Reservation Dam and White Rock Dam and their associated reservoirs, as well as the Bois de Sioux channel. A map displaying the project location can be found in **Figure 10**. Reservation Dam forms the impoundment of Lake Traverse. Reservation Dam can only control outflow to a maximum elevation of approximately 976.8 feet. When the pool exceeds that elevation, it spills into Mud Lake. Mud Lake is the reservoir behind White Rock Dam. When Mud Lake reaches an elevation of 976.8 feet, the level of Lake Traverse and Mud Lake essentially become one pool and control shifts to White Rock Dam.

A picture of White Rock Dam can be found in **Figure 11**. Construction of the Lake Traverse Project began in the latter part of 1939, and the project was completed in 1942. Pertinent data related the Lake Traverse Project can also be found in **Table 8**.

Table 8: White Rock Dam Pertinent Data

WHITE ROCK DAM-PERTINENT DATA			
Location: White Rock Dam is located in Traverse County, Minnesota, and Roberts County, South Dakota, at the headwaters of the Bois de Sioux River, approximately 30 miles south of Wahpeton, Minnesota. The dam is situated near latitude 45°51'45"N, Longitude 96°34'25"W.			
Total Drainage Area (Mud Lake & Lake Traverse): 1,160 Square Miles			
DESCRIPTION- WHITE ROCK DAM			
Type:	Rolled-Earth Fill	Maximum Height:	16 feet
Total Length:	14,400 feet	Top Width:	26 feet (roadway)
Volume of Dam	329,200 Cubic Yards	Freeboard:	4 feet (above SDF)
DESCRIPTION- RESERVATION DAM			
Type:	Rolled-Earth Fill	Maximum Height:	14.5 feet
Total Length:	9,100 feet	Top Width:	26 feet (roadway)
Volume of Dam	188,000 Cubic Yards	Freeboard:	Not Applicable
CONTROL STRUCTURES- WHITE ROCK DAM			
Type: Three Reversed Tainter Gages			

Table 8. Continued

Gate Width:	13.0 feet		
Gate Height:	16.0 feet		
Sill Elevation	965.0 feet		
Top of Gate (closed):	981.0 feet		
SPILLWAY AND CHUTE OUTLET			
	White Rock Dam		**Reservation Dam**
Type	Reinforced Concrete		Grouted Riprap Weir
Crest Elevation	965.0 feet		974.0 feet
Length of spillway crest	Three 16' H x 13'W Reversed Tainter Gates		15 Stoplog Bays 7'Hx 6'W and 2 Stoplog Bays 7'H x 5'9" W
Design Discharge:	5,600 cfs		5,600 cfs
STILLING BASIN-WHITE ROCK DAM			
Type:	Concrete Apron with dentated sill		
Width:	47 feet	**Rows of Baffle Blocks:**	2
Length:	34.07 feet	**Baffle Top El.:**	963.0 feet
Floor Elevation:	960.0 feet	**Sill Top Elevation:**	963.0 feet
RESEVOIR/CAPACITIES AREAS –White Rock DAM/MUD LAKE			
	Elevation (Feet)	**Capacity (Ac-Ft)**	**Area (Acres)**
Sill	965.00	0	
Conservation Pool	972.00	6,500	3,850
Top of Flood Control Pool	981.00	229,500	22,975
Maximum Pool	982.00	273,000	23,425
Flowage Easement Level	983.00	296,000	23,850
Top of Dam	986.00	368,000	24,800
RESEVOIR/CAPACITIES AREAS –RESERVATION DAM/LAKE TRAVERSE			
Sill	974.00	84,000	10,150
Conservation Pool	976.00	106,000	10,925
Top of Flood Control Pool	976.8	115, 000	11,200

Lake Traverse Reservoir is regulated between 974.0 feet (sill elevation) and 981.0 feet (top of flood control pool) (1912 MSL). If the late February basin-average snow water content is less than 3.0 inches (category I) Lake Traverse is lowered to an elevation of 975.5 feet by March 31st. If late February basin average snow water content is 3.0 inches or more (category II drawdown), the pool is lowered to 974.5 feet or lower by March 31st. Following spring runoff, stored floodwaters are evacuated as quickly as possible with consideration for target stages at Wahpeton, ND and utilization of the 1,100 cfs channel capacity below White Rock Dam. During flood control operations, discharges from

White Rock Dam are reduced to zero whenever the target stage at Wahpeton is exceeded. The Wahpeton target stage is 10' for a category I drawdown and 12' for a category II drawdown. If the reservoir pool exceeds elevation 981.0, the gates at White Rock Dam are raised completely.

3.1.2 Orwell Reservoir

Orwell Dam is located in the state of Minnesota on the Otter Tail River. The reservoir is approximately six miles southwest of Fergus Falls, Minnesota and about 55 miles southeast of Fargo, North Dakota. The drainage area associated with the reservoir can be found in **Table 9.** Orwell Dam was placed into operation during the spring of 1953. A map displaying project location can be found in **Figure 12**. A picture of Orwell Dam can be found in **Figure 13.**

The reservoir is regulated between a minimum elevation of 1050 feet (max. drawdown) and 1073.0 feet (top of surcharge pool) (1912 MSL). If the late February basin-average snow-water content is less than three inches, there is no drawdown and the conservation pool elevation of 1064.0 ± 0.5 feet is maintained (category I). If the late February basin average snow-water content is three inches or more, the pool may be drawn down to between elevations 1050.0 and 1060.0 feet (category II). The drawdown target elevation will be determined by Water Control. Drawdown begins on or after 1 March and is to be completed by 31 March. Maximum discharge will not exceed 1,200 cfs nor will the rate of fall exceed 0.5 feet/day.

As spring runoff begins, the storage capacity of the reservoir is utilized as needed to assist in preventing or reducing flood damages at Wahpeton-Breckenridge. See section 3.1.1 for target elevations at Wahpeton. If the pool elevation rises above the flood control pool elevation of 1070.0 feet, the discharge will be set to 90 percent of the inflow (based on the average inflow rate for the previous 3 hours), but not less than 1,200 cfs. If the pool elevation rises to the top of surcharge pool elevation of 1073.0 feet, the discharge is to be set equal to the inflow, but not less than 1,200 cfs. After the peak passes, the gate remains unchanged until the pool falls to elevation 1070.0 feet. **Table 9** gives detailed specifications for the dam and corresponding reservoir.

Table 9: Orwell Dam and Reservoir Pertinent Data

ORWELL DAM AND RESERVOIR			
Location: Orwell Dam is located on the Otter Tail River, 38.6 river miles upstream of Breckenridge, Minnesota, where the Otter Tail and Bois de Sioux Rivers combine to form the Red River of the North. The dam is situated in the southwest part of Otter Tail County, approximately 6 miles southwest of Fergus Falls, Minnesota, 55 miles southwest of Fargo, North Dakota, and 170 miles northwest of Minneapolis-St. Paul, Minnesota in Section 26, T132N, R44W near Latitude 46°13'0"N, Longitude 96°10'40"W.			
Total Drainage Area: **1,820 Square Miles**			
Real Estate Taking Guide Line Contour for Title in Fee: **Contour Elevation 1073.0 feet**			
DAM			
Type:	Rolled Earth Fill	Maximum Height:	47 feet
Total Length:	1,355 feet	Top Width:	20 feet
Crest Elevation:	1080.0 feet	Side Slopes:	1V:3H
CONTROL STRUCTURES			
Type:	One-Tainter Gate	Type:	Two-Low Flow Conduits
Gate Width:	33.0 feet	Shape/Location:	Circular/Abutments
Gate Height:	27.5 feet	Diameter:	2 feet
Gate Radius:	30.0 feet	Inlet Invert elevation:	1040.0 feet
Weir crest Elevation:	1044.0 feet	Control:	24 inch Slide Gates
Top of Gate (closed):	1071.5 feet		
Gate Seat Elevation:	1043.5 feet		
SPILLWAY AND CHUTE OUTLET			
Type:	Flared concrete Ogee	Type Chute:	Flared Concrete
Crest Elevation:	1044.0 feet	Width at Spillway Toe:	41.8 feet
Crest Width:	33.0 feet	Width at stilling basin:	54.5 feet
Width at Toe:	41.8 feet	Length:	38.2 feet
Maximum Recorded Discharge:	1,710 cfs on 17 Jun 1953	Slope:	IV:10H
		Design Discharge (PMF)	24,400 cfs
STILLING BASIN			
Type:	Flared with Baffles	Rows of baffle blocks:	2
Width at Chute:	54.5 feet	Baffle Block Height:	8.0 feet
Width at End Sill:	78.5 feet	End Sill Height:	8.0 feet
Floor Elevation:	1024.5 feet	End Sill Elevation:	1032.5 feet
		Length:	72.0 feet
ELEVATION – AREA - STORAGE			
	Elevation (ft)	**Area (acres)**	**Storage (acre-ft)**
Parapet Wall (I-wall):	1083.3		
Top of Dam:	1080.0	1,625	28,300
Tailwater Control Design Flood:	1078.8	1,700	26,320
Spillway Design Flood (PMF):	1075.0	1,400	20,500
Top of Surcharge Pool:	1073.0	1,300	17,750
Flood Control Pool:	1070.0	1,110	14,000
Conservation Pool:	1064.0	782	8,300
Intermediate Drawdown:	1060.0	598	5,500
Maximum Drawdown:	1050.0	264	1,200
Dead Storage (weir crest elev.):	1044.0	104	150

ORWELL DAM AND RESERVOIR (continued)	
HYDROLOGY:	
Total Drainage Area:	1,820 sq mi
Local Drainage Area (i.e. directly into the reservoir:	245 sq mi
Probable Maximum Flood (Tailwater Control Design Flood)	
Maximum Water Surface Elevation:	1078.8 ft
Peak Inflow:	26,200 cfs
Peak Outflow:	24,400 cfs
Total Flood Volume:	26,320 ac-ft
Climate:	Temperate
Flood Season:	Early Spring
Travel Time to Control Point (Wahpeton, ND):	12 to 24-hours
Minimum daily Flow:	Pre-Project: 5 cfs
	Post-Project: 5 cfs
	As of 1988: 80 cfs
Key Streamflow Locations:	Orwell Tailwater
	Wahpeton, ND
Hydrometeorologic Data Recorded at the Dam Site:	Pool & Tailwater Elevation
	24-hour Precipitation
	Periodic Water Quality
Snow Surveys:	1 Weekly at Dam Site
	1 Basin Surveys (9 locations)
Sediment Ranges:	24 Ranges, Last Survey 1985
RESERVOIR POOL:	
Maximum Pool Elevation:	1072.47 ft on 08 Jun 1999
Control Point for flood Operations:	Wahpeton,ND on red River
Target Stage at control Point:	
Category I (Normal runoff):	10 feet
Category II (Moderate to Heavy Runoff):	12 feet
No damage Channel Capacity:	1,200 cfs
Drawdown:	Begin 01 March; Complete 30 March
	Category I: No drawdown
	Category II: 1060 ft to 1050 ft
	Maximum Rate of Fall: 0.5 ft/day

3.1.3 Baldhill Dam/ Lake Ashtabula

Baldhill Dam, which creates the impoundment of Lake Ashtabula, is located on the Sheyenne River approximately 271 river miles upstream of the confluence with the Red River of the North, and about 16 river miles upstream of the community of Valley City. The drainage area associated with the reservoir can be found in **Table 10**. A map displaying project location can be found in **Figure 14**. A picture of Baldhill Dam can be found in **Figure 15**. Construction of Baldhill Dam was started in July 1947 under direction of the St. Paul District Engineer, and although not entirely completed, the project was placed into emergency operation on 16 April 1950. Permanent operations began in the spring of 1951.

Baldhill Dam is composed of compacted impervious earth fill and has an uncontrolled broad crest weir emergency spillway. The capacity of the structure, the maximum design pool elevation and the flood control storage capacity are listed in **Table 10**.

The reservoir is regulated between a minimum elevation of 1057 feet (max. drawdown) and 1071.0 feet (top of emergency spillway) (1929 NGVD). The flood control interest for the project is Valley City. However, should a significant rainfall event occur between Baldhill Dam and the city of Lisbon outflows from the dam may be cut in an effort to reduce flows at Lisbon. During the winter months, Lake Ashtabula is drawn down to provide flood storage for spring runoff. Winter drawdown is constrained between elevations of 1262.5 feet and 1257.0 feet. Channel full discharge is 2,400 cfs, Non-damaging discharge is 3,000 cfs, and the maximum sustainable discharge for Valley City with protective measures in place was found to be 6,500 cfs during the 2009 flood. A comprehensive list of details and specifications can be found in Table 12.

Table 10. Baldhill Dam and Lake Ashtabula

BALDHILL DAM PERTINENT DATA			
Location: Baldhill Dam is located on the Sheyenne River, approximately 271 river miles upstream of the confluence with the Red River of the North and about 16 river miles upstream of Valley City, North Dakota. The dam is situated in the North-central part of Barnes County in North Dakota, near Latitude 47°02'09"N, Longitude 98°04'52"W.			
Total Drainage Area: **3,812 Square Miles**			
DAM			
Type:	Compacted Impervious Earth Fill	Maximum Height:	61 feet
Total Length:	1,650 feet	Top Width:	20 feet
Crest Elevation:	Top of Earth Dam: 1278.5 feet	Freeboard:	5.0 feet above PMF
	Top of Tee-Wall: 1283.5 feet		

BALDHILL DAM PERTINENT DATA (continued)			
EMERGENCY SPILLWAY AND SERVICE SPILLWAY.			
Type of Emergency Spillway:	Uncontrolled Broad Crest Weir	Type of Service Spillway:	Gravity Ogee
Crest Elevation:	1271.0 feet	Gates:	Tainter, 3 @ 40-ft wide, 20 ft high
Length:	880 feet	Crest:	Elevation 1252.0 feet
		Length:	3 Bays; 140 feet total
Type of Low Flow Outlet:	Two, 36-inch reinforced concrete conduits		
Intake Invert:	Elevation 1238.0 feet		
Discharge Invert:	Elevation 1234.5 feet		
RESERVOIR POOL DATA			
Outflow:			
Probable Maximum Flood:			
Service Spillway:	66,200 cfs		
Emergency Spillway:	57,800 cfs		
Total Discharge:	124,000 cfs		
Channel Full Discharge:	24000cfs		
Non-Damaging Discharge:	3000cfs		
Minimum Discharge:	13 cfs		
	Pool Elevation (feet)	**Pool Storage (Ac-ft)**	**Pool Area (Acres)**
Probable Maximum Flood:	1278.5	157,500.0	8500.0
Top of Flood Control:	1271.0	101,300.0	6750.0
Conservation Pool Level:	1266.0	70,600.0	5500.0
Normal Drawdown:	1262.5	52,250.0	4375.0
Maximum Drawdown:	1257.0	31,000.0	3000.0
Dead Storage:	1238.0	500.0	250.0
HYDROLOGY:			
Sheyenne River Basin Total:	10700 square miles		
Closed Basins:			
Devils Lake Basin:	3573 square miles		
U/S Warwick Gage:	227 square miles		
Contributing Drainage Area:	4850 square miles		
Non-Contributing Area:	2050 square miles		

BALDHILL DAM PERTINENT DATA (continued)	
Baldhill Dam:	
Primary Drainage Area:	1690 square miles
Secondary Drainage Area:	1660 square miles
Non-Contributing Area:	462 square miles
Total Drainage Area:	3812 square miles
Minimum Daily Outflow:	
Pre-Dam Construction:	0.0 cfs
Post-Dam Construction:	1.0 cfs (9 Sept. - 5 Oct. 1955)
	6.0 cfs (15 July 1988)
Minimum Monthly Outflow:	1.3 cfs (Sept. 1955)
Minimum Annual Outflow:	46.7 cfs (1988)
Maximum Instantaneous Outflow:	5460 cfs (April 1996)
Minimum Monthly Inflow:	-95 cfs (Based on 24-hr average daily inflow; does not include pool evaporation)
Maximum Monthly Inflow:	4266 cfs (Apr. 1997)
24-Hour Peak Inflow:	8810 cfs (Apr. 1979)
Peak Source Inflow:	7830 cfs (Cooperstown, May 1950)
	~9000 cfs (Dazey, Apr. 1979)
Key Stream Locations:	
Upstream Sheyenne River:	Warwick, Cooperstown
Upstream Baldhill Creek:	Dazey
Downstream Sheyenne River:	Valley City, Lisbon
Snow Survey Sites:	Baldhill, Cooperstown, Warwick, Maddock, New Rockford, Lisbon, Colgate, Dazey, Aneta, Fort Trotten, Hamberg, McHenry
	Enderlin, Kindred, Fingal, Hannaford, McVille, Minnewakan, Sheyenne, Tower City, Fort Ransom, Amenia
Sediment Ranges:	30 Ranges (Disregard the 1978 survey)
	Survey Dates: 1952, 1958, 1964, 1971, 1978, 1984
RESERVOIR POOL:	
Control Point for flood Operations:	Valley City, ND on Sheyenne River
Minimum daily Flow:	Pre-Project: 0.0 cfs
	Post-Project: 1.0 cfs; 9 Sept. - 5 Oct. 1955
	As of 15 July 1988: 6.0 cfs
Key Streamflow Locations:	Baldhill Tailwater
	Valley City, ND

3.1.4 Red Lake Dam

The Red Lake River Basin lies entirely within northwestern Minnesota with the north edge of the basin being 40 to 50 miles south of the International Boundary. Red Lake Dam impounds the Red Lake Reservoir which consists of Upper and Lower Red Lakes. The reservoir is located in the eastern portion of the Red Lake River Basin. The lakes are connected by a small strait about 1 mile wide, known as the narrows. Most of the inflow into Red Lakes comes from the Tamarac and Battle Rivers. The lakes are shallow and the shores are very flat. All of Lower Red Lake and about one half of the Upper Red Lake lie within the Red Lake Indian Reservation. The drainage area associated with the reservoir can be found in **Table 11**. A map displaying the project location can be found in **Figure 16**.

A picture of Red Lake Dam can be found in **Figure 17**. In 1931 the United States Department of the Interior, Office of Indian Affairs, constructed a control structure at the outlet of Lower Red Lake. The control structure was modified and regulation of lake stages with normal pool elevation at 1174.0 (MSL 1912) was authorized by Congress in 1944 and construction was complete by 1951. Pertinent data related to Red Lake Dam Project can also be found in **Table 11**.

Table 11: Red Lake Dam Pertinent Data

RED LAKE DAM-PERTINENT DATA			
Location: Red Lake Dam is located at the outlet of the Lower Red Lake in the northeastern part of Clearwater County, MN, approximately 18 miles northwest of the village of Red Lake, MN and 196.0 river miles above the mouth of the Red Lake River.			
Total Drainage Area: 1, 951 square miles			
DESCRIPTION			
Type:	Earth dike road	**Maximum Height:**	15.5 feet
Total Length:	36,500 ft	**Crest Elevation:**	1181.5 ft m.s.l
Volume of Dam	140,285 cubic yards	**Freeboard:**	2.5 ft above Max prob. Lake El.
OUTLET STRUCTURES			
Type: Gated Broad Crested Weir			
Crest Elevation	1169.6 ft m.s.l		
Length of Crest	64 ft		
Design Discharge:	3,700 cfs		
Gates:	3- 16x5 lift gates, 2- 8x5 stop log sections		
Stilling Basin:	Rectangular		
Width of Stilling Basin :	71.5 feet		
Length of Stilling Basin:	12 feet		
Stilling Basin Floor Elevation:	1165.0 feet m.s.l		
RESEVOIR/CAPACITIES AREAS			
Maximum probably Lake Elevation	1179.03 ft m.s.l		
Capacity at Max probable Lake Elevation	3,270,000 acre-feet		
Normal Lake Elevation	1174 ft m.s.l		
Capacity at normal Lake Elevation	1,810,000 acre-feet		
Area at normal Lake Elevation	288, 800 acres		

Normal pool elevation is 1174.0, however, the pool is lowered to elevation 1173.5 annually to provide storage capacity for the spring runoff. Available storage for flood runoff between elevations 1173.5 and 1177.0 is about 1,010, 00 acre-feet. Just prior to spring thaw, the discharge from the Red Lakes Dam is cut to a token flow necessary to sustain fish and wildlife and for other downstream needs. The dam is kept at this low discharge until high water downstream has abated.

3.2 1997 SPRING FLOOD

By early January, record snowfall levels had occurred over much of the Red River of the North basin. As can be seen in **Table 12**, this resulted in high snow water equivalent (SWE) in the basin.

Table 12. 1997 SWE in the Red River Basin

Location	1997 Max Weekly Snow Water Equivalent (Inst-Cum, Inches)	Average Annual Max Weekly Snow Water Equivalent (Inst-Cum, Inches)
Lake Traverse	7.93	2.68
Orwell Reservoir	7.87	2.12
Baldhill Dam	7.87	3.00

Source: USACE St. Paul District Water Control Website (data for Red Lake Dam is not available)

In late March, initial snowmelt began. This resulted in the flood's first peak. On 4-6 April, the blizzard 'Hannah' hit the basin dropping 10 to 14 inches of wet snow. The storm was followed by several days of abnormally low temperatures, thus retarding runoff. The cool period was followed by warm weather which led to a second peak. Inflow and outflow Hydrographs, as well as pool elevations related to the 1997 Spring floods for Lake Traverse, Orwell Reservoir, Lake Ashtabula and Red Lake can be found in **Figure 18-Figure 21**.

3.2.1 White Rock Dam/ Lake Traverse

During the 1997 Spring Flood Event Lake Traverse was drawn down between March 1st and March 25th. With the high snow water equivalent (SWE) in the basin, the reservoir was drawn down to 974.5 (CAT II drawdown). By April 4th, releases out of White Rock dam were ramped up to 1,100 cfs (downstream channel capacity). Inflow peaked at 15, 699 cfs on the 6th of April. White Rock was closed on April 5t. Releases from White Rock Dam were ramped up once more starting on the 10th of April and reach a maximum outflow of 7,740 cfs on April 19th. Lake Traverse stage peaked at 982.21 feet on April 16th. White Rock Dam releases consistently equaled or exceeded downstream channel capacity (1,100 cfs) until mid-June.

In 1997 the Red River of the North peaked at 12,800 cfs at Wahpeton, ND (just downstream of White Rock Dam) on April 15th. Discharges from White Rock Dam were reduced to zero on April 5th. Flows were not released from the dam again until April 9th when the pool elevation exceeded 981.0 feet and gates at White Rock Dam were raised. As a result of the gates being raised 7, 220 cfs of flow was released from the dam on April 15th. The pool elevation did not fall below 981.0 feet until the 20th of April and during that time the gates at White Rock Dam were raised clear of the water surface allowing for uncontrolled outflow from the dam. In this case outflows from White Rock Dam were unregulated at the time of 1997 peak on the Red.

3.2.2 Orwell Reservoir

Drawdown of the pool was started one month sooner than normal operating procedures to avoid large releases and ensure maximum drawdown before spring snow-melt and runoff. Drawdown of the pool began on 1 February and on 30 March, the pool reached its minimum allowable elevation of 1048.0 feet. On 6 April, a record stage of 19.42 feet was recorded at Wahpeton. The snow melt, combined with increased releases from White Rock Dam, resulted in a second crest at Wahpeton of 19.37 feet on 16 April. On 15 April, the USGS measured a discharge of 12,800 cfs at the Wahpeton gage site and estimated overland flow to the Wild Rice River basin, about seven miles upstream of the gage, to be 2,200 cfs. The Orwell Reservoir reached a maximum pool elevation of 1070.30 feet on 15 April with a peak discharge of 1,520 cfs occurring on the following day (16 April). Orwell Reservoir discharges exceeded 1,000 cfs continuously from 12 April through 25 June.

3.2.3 Baldhill Dam/ Lake Ashtabula

By the end of March the pool had been drawn down to elevation 1257.0 feet (maximum drawdown). As a result of the blizzard Hannah, inflow to the reservoir dropped off from 5,000 cfs to 1,100 cfs in early April. The cool period was followed by warm weather. Inflow to reservoir increased daily until it crested on 19 April with a 24-hour peak of 6,660 cfs. Outflow crested the same day at 4,510 cfs. The pool crested on 30 April at 1267.51 feet.

3.2.4 Red Lake Dam

By the end of March the pool had been drawn down to 1173.89. Releases out of Red Lake Dam were decreased to 75 cfs on April 16 and were not increased again until the 16th of May.

3.3 2001 SPRING/ SUMMER FLOOD

As can be seen in **Table 13**, the winter of 2001 was characterized by high snow water equivalent (SWE) in the Red River Basin.

Table 13. 2001 SWE in the Red River Basin

Location	Max Weekly Snow Water Equivalent (Inst-Cum, Inches)	Average Annual Max Weekly Snow Water Equivalent (Inst-Cum, Inches)
Lake Traverse	5.74	2.68
Orwell Reservoir	3.00	2.12
Baldhill Dam	3.50	3.00
Source: USACE St. Paul District Water Control Website (data for Red Lake Dam is not available)		

Spring runoff was followed by intermittent rainfall events which kept inflows into the region's reservoirs high until mid-summer. Inflow and outflow Hydrographs, as well as pool elevations related to the 2001 Spring/ Summer floods for Lake Traverse, Orwell Reservoir, Lake Ashtabula and Red Lake can be found in **Figure 22- Figure 25**.

3.3.1 White Rock Dam/ Lake Traverse

During the 2001 Spring Flood Event Lake Traverse was drawn down between February 27th and March 31st to 974.08. On April 10th, inflow into the reservoir peaked at 11,635 cfs. By April 20th, Releases out of White Rock Dam were ramped up to a peak of 3,750 cfs. A maximum stage of 981.12 was reached on April 19th. Over the next few months releases from the reservoir remained high. White Rock Dam releases consistently equaled or exceeded downstream channel capacity (1,100 cfs) until late July.

In 2001 the Red River of the North peaked at 9, 340 cfs at Wahpeton, ND on April 9th. The coincident flow out of White Rock dam on April 9th was only 1, 400 cfs. At that point discharge from White Rock Dam was being governed by the requirement to maintain Mud Lake at an elevation of 972 feet, while attempting to minimize the stage at Wahpeton and to stay as close as possible to channel capacity (1, 100 cfs). In this case operators at White Rock Dam minimized the peak on the Red River by reducing the outflows being released from White Rock Dam.

3.3.2 Orwell Reservoir

Reservoir drawdown was initiated on the 1st of March. On the 31st of March, the target drawdown elevation of 1053.0 feet was achieved. Spring runoff began on the 6th of April with inflows rising to over 1, 500 cfs by the 8th of April. Outflow was maintained at the channel capacity discharge of 1,200 cfs. By the 22nd of April, inflow had fallen to 1,170 cfs, when 1.3 inches of rainfall was recorded at the dam. Inflows again rose above 1, 500 cfs while outflows remained at 1,200 cfs. Over the next two months, inflow was supplemented with intermittent rainfall events, thus keeping inflows on the high side. On 16 May, the pool reached an elevation of 1070.0 feet, at which time outflow was set at 90 percent of inflow. With sustained high inflow, top of surcharge (elevation 1073.0 feet) was reached on 29 May and outflow was set equal to inflow. Over the next month, intermittent rainfall events resulted in a very slow fall in inflow rates. The pool did not fall below top of flood control (elevation 1070.0 feet) until the 1st of July. Conservation pool level was reached on 20 July.

3.3.3 Baldhill Dam/ Lake Ashtabula

During the 2001 spring flood event Lake Ashtabula was drawn down to 1257.13 feet during the month of March. By drawing the pool down prior to spring runoff the Lake Ashtabula Stage and releases out of the dam could be kept relatively low. Reservoir stage only reached a maximum of 1266.27 and the maximum release out of the dam was 2,390 cfs (below the bankfull condition of 2,400).

3.3.4 Red Lake Dam
By the end of March the pool had been drawn down to 1173.82. Releases out of Red Lake Dam were decreased to 75 cfs on April 10 and were not increased again until the 18th of April.

3.4 2006 SPRING FLOOD

During the fall of 2005 above-normal precipitation occurred in many areas in the Red River of the North Basin. Snow pack in many parts of the basin reached 300 percent of normal by early 2006. Snow water equivalent in the basin was relatively high as can be seen in **Table 14.**

Table 14. 2006 SWE in the Red River Basin

Location	Max Weekly Snow Water Equivalent (Inst-Cum, Inches)	Average Annual Max Weekly Snow Water Equivalent (Inst-Cum, Inches)
Lake Traverse	3.58	2.68
Orwell Reservoir	3.20	2.12
Baldhill Dam	3.56	3.00
Source: USACE St. Paul District Water Control Website		

The 2006 flood event began in late March in the southern part of the basin. Between March 30th and 31st, 1.25 inches of rain fell on the southern portion of the basin acerbating flooding. Inflow and outflow Hydrographs, as well as pool elevations related to the 2006 Spring floods for Lake Traverse, Orwell Reservoir and Lake Ashtabula can be found in **Figure 26** through **Figure 28**.

3.4.1 White Rock Dam/ Lake Traverse

During the 2006 Spring Flood Event Lake Traverse was drawn down between March 1st and March 22nd. With the high snow water equivalent (SWE) in the Red River Basin the draw down goal was set at 974.5 (CAT II). The pool was drawn down to 974.82 on 22nd March, 2006. Inflow into Lake Traverse peaked on March 31st at 8,184 cfs. White Rock Dam was closed on the 31st of March to help the city of Wahpeton, ND. It was opened again on the 9th of April. The Peak outflow from White Rock Dam was 1,320 cfs on April 14th. Lake Traverse peaked at 978.37 feet on April 11th.

3.4.2 Orwell Reservoir

During the 2006 Spring Flood Event Orwell was drawn down between March 1st and March 28th. With the high amounts of SWE in the Red River Basin the goal was to draw down the pool to its max elevation (1050.0 feet). On March 28th the pool was at 1052.65 feet (NGVD 29). The pool rose to a peak of 1068.17 on April 14th 2006. Inflow into the reservoir peaked on the 1st of April at 1, 294 cfs. The corresponding peak outflow occurred on April 27th at 1,230 cfs. A second peak inflow occurred on the 25th of May at 1, 766 cfs. This second peak caused the pool elevation to reach 1071.26 on the 28th of

May. The corresponding peak outflow was 1,510 cfs between the 26th of May and the 1st of June.

3.4.3 Baldhill Dam/ Lake Ashtabula

With the wet fall, a sampling of snow surveys in January and the full survey at the end of February, the goal was to drawdown Lake Ashtabula between mid to late March. 1260.27 feet was reached on March 29th. Melting started in late March in the southern part of the valley. A peak inflow of around 1,927 cfs occurred on April 4th. Between April 11th and April 17 around 1,300 cfs was released from the dam.

3.5 2009 SPRING FLOOD

The fall of 2008 was very wet. September – December had above normal precipitation. Soil moisture was extremely saturated at freeze up, and there was minimal snow cover until mid-December (with below freezing temperatures). North Dakota had record snowfall totals in December. Snow water equivalent in the basin was relatively high as can be seen in **Table 15.**

Table 15. 2009 SWE in the Red River Basin

Location	Max Weekly Snow Water Equivalent (Inst-Cum, Inches)	Average Annual Max Weekly Snow Water Equivalent (Inst-Cum, Inches)
Lake Traverse	3.10	2.68
Orwell Reservoir	3.00	2.12
Baldhill Dam	3.50	3.00
Source: USACE St. Paul District Water Control Website (data for Red Lake Dam is not available)		

Heavy rain March 22-25 added to the flooding. A snowstorm at the end of March added 1-2 inches of SWE to the southern part of the Red River Basin. Inflow and outflow Hydrographs, as well as pool elevations related to the 2009 Spring floods for Lake Traverse, Orwell Reservoir, Lake Ashtabula and Red Lake can be found in **Figure 29** through **Figure 32**.

3.5.1 White Rock Dam/ Lake Traverse

During the 2009 Spring Flood Event Lake Traverse was drawn down between March 1st and March 31st. With the high snow water equivalent (SWE) in the Red River Basin the draw down goal was set at 974.5 (CAT II). With the warm up on March 16th the pool stopped falling at 975.46 feet. Inflow into Lake Traverse peaked at 8,200 cfs on March 23rd. White Rock Dam was closed on March 20th to help the city of Wahpeton, ND. It was opened again on March 29th. The Peak outflow from White Rock Dam was 3,700 cfs on April 3. White Rock Dam decreased its releases on April 11th for two days to help attenuate the effects of a second peak at Wahpeton. Lake Traverse peaked at 980.73 feet on March 31st and was back in band on May 8th.

In 2009 the Red River of the North peaked at 10,400 cfs on March 24th. Discharges from White Rock Dam were not reduced to zero on the 21st of March. Flows were not released from the dam again until the 29th of March when the peak flow on the Red River had already moved downstream.). In this case operators at White Rock Dam minimized the peak on the Red River by reducing the outflows being released from White Rock Dam.

3.5.2 Orwell Reservoir

During the 2009 Spring Flood Event Orwell was drawn down between March 1st and March 31st . With the high amounts of SWE in the Red River Basin the goal was to draw down the pool to its max elevation (1050.0 feet). On March 15th the pool was at 1058.5 feet (NGVD 29). With the warm-up on March 16, the pool rose to 1060.0 feet by March 18th, before reaching 1058.2 feet on March 22nd. At noon on March 22nd outflow was decreased by ~500 cfs and held for two days until the peak had passed at Wahpeton. Inflow into the reservoir peaked at 2,180 cfs on March 23. On March 24 Wahpeton crested at 17.5 feet. A second inflow peak of 1,900-1,960 cfs occurred from April 15 till May 13. Inflow was back below channel capacity of 1,200 cfs on July 2nd.

3.5.3 Baldhill Dam/ Lake Ashtabula

With the wet fall, a sampling of snow surveys in January and the full survey at the end of February, the goal was to drawdown Lake Ashtabula to 1257.0 (NGVD 29) (max drawdown) between mid to late March. 1257.10 feet was reached on March 19th. Melting started on March 16th in the southern part of the valley. A first peak inflow of around 7,200 cfs occurred on March 25th. Releases during the first peak were between 300 and 500 cfs. From March 26th -29th releases were ramped up to around 3,400 cfs. The pool reached 1265.25 on March 28th. Because of the large amount of SWE left in the valley the pool was down to 1257.00 feet again. The second melt started earlier than expected with the pool at 1260.47 feet (rain driven melt). The second peak inflow was close to 9,000 cfs on April 13th. At that point releases had been ramped up to 6,000 cfs. Maximum discharge was around 6,600 cfs (setting a new record) on April 16th. The pool peaked on April 24th at 1269.47 feet. It was thought that the secondary contributing area would contribute more than it actually did. Maximum drawdown (1257 feet) at Baldhill was achieved on Mar 19th . Baldhill was operated to maximize its storage and minimize its outflow in order to protect Valley City downstream.

3.5.4 Red Lake Dam

In the beginning of March the pool was at El. 1174.09. Releases from the dam were decreased to 44 cfs on March 21st. Between March 21st and March 24th and between March 29th and April 2nd releases were kept under 100 cfs.

3.6 REGULATED VS. UNREGULATED CONDITION

3.6.1 Reservoir Effects on Flood Stage

Following the 2009 spring flood event modeling of the regulated vs. unregulated condition was carried out for the Annual Flood Damage reduction (AFDR). Based on the modeling results Orwell, Traverse and the Ottertail Diversion reduced the stage at Wahpeton by approximately 7 feet and Fargo by 1.8 feet in comparison to the unregulated condition. Baldhill reduced stage at Valley City by 2.3 feet and Lisbon by 1 foot in comparison to the natural condition.

3.6.2 Regulated vs. Unregulated Flow Record

Instantaneous observed flows from 1942-2009 are used to represent the regulated condition. White Rock Dam and its downstream gage, were put into operation in 1942. Of the two dams located upstream of Fargo, ND (White Rock Dam and Orwell Dam), White Rock Dam has the most effect on the flows on the Red River at Fargo, ND, due to its larger flood storage capacity.

Orwell Dam was not put into operation until 1953; however, the USGS gage downstream of Orwell Dam was in operation since 1931. Flows at Orwell Dam between 1942 and 1953 were adjusted for regulation using HEC-5 in order to render a homogenous flow set, so that the White Rock Dam flow series could be used since 1942.

The rule curves for the two reservoirs have not changed significantly since their inception. There is some discretion in how they operate during floods. Replicating exact operation is not possible.

The effects of the reservoirs diminish considerably downstream of Fargo, ND due to increasing incremental drainage area. Therefore, flow-frequency analysis for stations downstream of Fargo, ND can be considered the same for both the regulated and the unregulated condition.

3.6.3 Reservoir Effects on Flow Frequency Analysis

Regulation has the least effect on moderate events and on events that reach the 0.2% event level and beyond. Regulation has the greatest effect on events that occur frequently and on the 2%, 1%, and 0.5% event. This is evident from the preliminary Flow-Frequency curves produced by the Hydrologic Engineering Center. The comparative curves generated by HEC for the WET and DRY condition can be seen in **Figure 33** and **Figure 34**, respectively. Furth comparison between regulated and unregulated flows for the combined scenarios (50-yr and 25-yr look-a-head) can be found in **Table 16.** The analysis used to generate these curves will be presented in Appendix A1-c.

Table 16- Unregulated vs. Regulated Flow-Frequency Curves at Fargo

Exceedance Frequency	Wet			25-yr Combined			50-yr Combined		
	Regulated Flow (cfs)	Unregulated Flow (cfs)	% Difference	Regulated Flow (cfs)	Unregulated Flow (cfs)	% Difference	Regulated Flow (cfs)	Unregulated Flow (cfs)	% Difference
0.9999	50	91	45%	50	77	35%	50	72	31%
0.999	150	211	29%	119	157	24%	112	141	21%
0.99	400	553	28%	288	371	22%	257	320	20%
0.9	1,400	1,837	24%	967	1,215	20%	804	984	18%
0.75	2,700	3,479	22%	1,950	2,460	21%	1,577	1,945	19%
0.5	5,500	6,737	18%	4,261	5,276	19%	3,436	4,253	19%
0.25	10,500	12,417	15%	8,867	10,599	16%	7,536	9,085	17%
0.1	17,000	20,672	18%	15,334	18,550	17%	13,858	16,688	17%
0.05	22,000	27,551	20%	20,345	25,258	19%	18,855	23,217	19%
0.02	28,500	37,482	24%	26,861	34,935	23%	25,374	32,649	22%
0.01	34,000	45,612	25%	32,185	42,910	25%	30,538	40,475	25%
0.005	43,000	54,256	21%	39,955	51,389	22%	37,254	48,798	24%
0.002	57,500	66,442	13%	53,702	63,351	15%	50,328	60,549	17%

4. PERIOD OF RECORD DISCHARGE-FREQUENCY ANALYSIS

Discharge frequencies for the reach upstream of Fargo and downstream of Wahpeton, ND, were determined by including the discharge-frequencies at Hickson. Another gage was used for the Wild Rice River-ND that enters within this reach. The flows at Abercrombie were used to determine coincidental flows for the respective discharge-frequencies for the Red River.

4.1 RED RIVER AT FARGO, ND

4.1.1 General

The annual instantaneous peak discharge - frequency relationship for the Red River of the North at Fargo is based upon period of record flows available at the Fargo streamflow gaging station. Computer program HEC-FFA (**reference 2**) was used with observed streamflow values from 1902 through 2009 along with historic flood data for 1882 and 1897. The two-station comparison method was investigated for adjusting the statistics of the Fargo station on the basis of regression analysis with the longer record available at the Grand Forks station. The improvement in the statistics was considered so minor such that the Fargo streamflow records were utilized on their own for development of the frequency curve used for this particular study.

Because of regulation effects from the upstream reservoirs at White Rock Dam and Ottertail Dam, adjustments in the recorded data set was required to obtain a homogeneous record based on the current regulated condition. First the natural flows prior to 1942 when Lake Traverse went into operation were adjusted to the current regulated condition. Second, once the full record from 1902 to 2009 was determined a graphical frequency analysis was done to reflect regulation effects.

To aid in drawing the regulated condition curve, an upper bound natural condition curve was generated. This curve would provide a guide for the upper end of the regulated curve. Synthetic events were also simulated from the upstream reservoirs, routed and combined at Fargo, and used to guide the upper end of the curve.

4.1.2 Natural Condition

4.1.2.1 Mean Daily Peaks

For this condition, actual recorded flows were used up to the year 1942. Flows from 1942 to the present were adjusted to the natural condition by routing flows from Lake Traverse and Orwell Dam. The gage outflows at these locations were "reverse routed" through the respective reservoirs to arrive at the natural condition inflows. The incremental local flows at the downstream computation points at Wahpeton, Hickson, and Fargo were determined by routing the observed flows and subtraction. The HEC-5 model **(reference 3)** was used to accomplish the routings.

The resulting flows at Fargo were considered to be mean daily flows and the annual peaks were then input to HEC-FFA for analysis of the natural, mean daily, annual peak, discharge-frequency. This curve is shown as **Figure 35. Table 17** lists the natural, annual mean daily, peak flows.

Table 17 Fargo Natural Annual Mean Daily Peak Flows

-PLOTTING POSITIONS-FARGO USGS GAGE NO. 05054000 W/O RESERVOIRS

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	FLOW CFS	RANK	WATER YEAR	FLOW CFS	MEDIAN PLOT POS
4	11	1882	19800.	1	2009	33353.	.64
5	23	1902	1180.	2	1969	32587.	1.55
4	6	1903	2450.	3	1997	31391.	2.47
6	28	1904	2830.	4	2001	28487.	3.38
5	17	1905	4250.	5	2006	26294.	4.30
4	9	1906	3050.	6	1978	22135.	5.21
6	17	1907	4420.	7	1989	21768.	6.12
6	13	1908	2600.	8	1952	21329.	7.04
5	30	1909	1780.	9	1979	21065.	7.95
3	20	1910	4700.	10	1882	19800.	8.87
4	11	1911	608.	11	1943	19409.	9.78
5	14	1912	1100.	12	2007	15516.	10.69
7	8	1913	1460.	13	1966	14706.	11.61
6	12	1914	3060.	14	1995	14418.	12.52
7	2	1915	3110.	15	1965	13823.	13.44
7	11	1916	7720.	16	1994	13654.	14.35
4	3	1917	5200.	17	1975	13404.	15.27
3	30	1918	750.	18	1986	13332.	16.18
3	22	1919	630.	19	1993	13294.	17.09
3	27	1920	6120.	20	2005	12345.	18.01
4	6	1921	1970.	21	1984	12196.	18.92
4	11	1922	5200.	22	1962	11709.	19.84
6	29	1923	3960.	23	1947	11514.	20.75
4	30	1924	530.	24	1996	11075.	21.66
6	20	1925	885.	25	1951	10881.	22.58
3	24	1926	1600.	26	1972	9730.	23.49
3	19	1927	2650.	27	1950	9156.	24.41
3	28	1928	3840.	28	1998	9152.	25.32
3	20	1929	4440.	29	2003	9026.	26.23
3	17	1930	1340.	30	1945	8634.	27.15
4	3	1931	365.	31	1916	7720.	28.06
4	11	1932	868.	32	1946	7540.	28.98
4	5	1933	605.	33	1982	7213.	29.89
4	10	1934	323.	34	1944	7001.	30.80
3	19	1935	930.	35	1963	6564.	31.72
4	14	1936	1050.	36	1953	6554.	32.63
4	12	1937	1300.	37	1967	6442.	33.55
5	2	1938	1160.	38	2008	6367.	34.46
3	31	1939	3600.	39	1980	6317.	35.37
4	7	1940	970.	40	1920	6120.	36.29
4	3	1941	1390.	41	2002	5973.	37.20
6	12	1942	5258.	42	2004	5905.	38.12
4	7	1943	19409.	43	1985	5623.	39.03
6	9	1944	7001.	44	1942	5258.	39.95
3	22	1945	8634.	45	1999	5227.	40.86
3	27	1946	7540.	46	1922	5200.	41.77
4	15	1947	11514.	47	1917	5200.	42.69
4	10	1948	4893.	48	2000	5162.	43.60
7	14	1949	3412.	49	1948	4893.	44.52
4	7	1950	9156.	50	1910	4700.	45.43
4	11	1951	10881.	51	1929	4440.	46.34

Table 17. Continued

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	FLOW CFS	RANK	WATER YEAR	FLOW CFS	MEDIAN PLOT POS
4	16	1952	21329.	52	1907	4420.	47.26
6	1	1953	6554.	53	1905	4250.	48.17
6	12	1954	2524.	54	1960	4139.	49.09
4	4	1955	2943.	55	1974	4088.	50.00
4	**16**	**1956**	**3789.**	**56**	**1923**	**3960.**	**50.91**
4	26	1957	3690.	57	1928	3840.	51.83
7	6	1958	2320.	58	1956	3789.	52.74
7	4	1959	1866.	59	1991	3710.	53.66
4	8	1960	4139.	60	1957	3690.	54.57
5	21	1961	947.	61	1939	3600.	55.48
5	29	1962	11709.	62	1976	3460.	56.40
6	14	1963	6564.	63	1949	3412.	57.31
4	18	1964	2587.	64	1987	3131.	58.23
4	15	1965	13823.	65	1915	3110.	59.14
3	22	1966	14706.	66	1914	3060.	60.05
6	19	1967	6442.	67	1906	3050.	60.97
4	30	1968	1172.	68	1955	2943.	61.88
4	15	1969	32587.	69	1904	2830.	62.80
6	18	1970	2483.	70	1971	2751.	63.71
3	22	1971	2751.	71	1992	2700.	64.63
3	24	1972	9730.	72	1927	2650.	65.54
3	19	1973	2158.	73	1908	2600.	66.45
4	14	1974	4088.	74	1964	2587.	67.37
7	5	1975	13404.	75	1954	2524.	68.28
3	30	1976	3460.	76	1970	2483.	69.20
5	5	1977	749.	77	1903	2450.	70.11
4	3	1978	22135.	78	1958	2320.	71.02
4	19	1979	21065.	79	1973	2158.	71.94
4	6	1980	6317.	80	1921	1970.	72.85
5	24	1981	1839.	81	1959	1866.	73.77
4	5	1982	7213.	82	1981	1839.	74.68
7	4	1983	1790.	83	1983	1790.	75.59
4	2	1984	12196.	84	1909	1780.	76.51
6	5	1985	5623.	85	1926	1600.	77.42
4	3	1986	13332.	86	1913	1460.	78.34
10	1	1986	3131.	87	1941	1390.	79.25
3	31	1988	1067.	88	1930	1340.	80.16
4	9	1989	21768.	89	1937	1300.	81.08
6	2	1990	963.	90	1902	1180.	81.99
7	7	1991	3710.	91	1968	1172.	82.91
6	19	1992	2700.	92	1938	1160.	83.82
4	6	1993	13294.	93	1912	1100.	84.73
4	1	1994	13654.	94	1988	1067.	85.65
3	22	1995	14418.	95	1936	1050.	86.56
4	16	1996	11075.	96	1940	970.	87.48
4	12	1997	31391.	97	1990	963.	88.39
3	2	1998	9152.	98	1961	947.	89.31
6	10	1999	5227.	99	1935	930.	90.22
6	20	2000	5162.	100	1925	885.	91.13
4	15	2001	28487.	101	1932	868.	92.05
7	15	2002	5973.	102	1918	750.	92.96
6	30	2003	9026.	103	1977	749.	93.88
6	4	2004	5905.	104	1919	630.	94.79
6	18	2005	12345.	105	1911	608.	95.70
4	5	2006	26294.	106	1933	605.	96.62
6	8	2007	15516.	107	1924	530.	97.53
6	16	2008	6367.	108	1931	365.	98.45
3	28	2009	33353.	109	1934	323.	99.36

4.1.2.2 Instantaneous Peak Flows

Once the period of record mean daily flows were determined, they were adjusted upward to obtain the natural, instantaneous, annual peak, flows and discharge-frequency.

Adjustment of the peak, mean daily, flows was accomplished by regression of recorded mean daily peaks and instantaneous peaks from 1942 to 2009. For the period prior to 1942, actual recorded instantaneous peaks were used. **Figure 36** shows the regression analysis and **Figure 37** shows the analytical curve. **Table 18** lists the annual, instantaneous peak flows for the without dams condition (natural).

Table 18 Fargo Natural Annual Instantaneous Peak Flows

-PLOTTING POSITIONS-FARGO USGS GAGE NO. 05054000 W/O RESERVOIRS

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	FLOW CFS	RANK	WATER YEAR	FLOW CFS	MEDIAN PLOT POS
4	11	1882	20000.	1	2009	33753.	.64
5	23	1902	1180.	2	1969	32978.	1.55
4	6	1903	2450.	3	1997	31768.	2.47
4	20	1904	5220.	4	2001	28829.	3.38
5	17	1905	4250.	5	2006	26610.	4.30
4	9	1906	3050.	6	1978	22401.	5.21
3	31	1907	7000.	7	1989	22029.	6.12
6	13	1908	2600.	8	1952	21585.	7.04
5	30	1909	1780.	9	1979	21318.	7.95
3	19	1910	5000.	10	1882	20000.	8.87
4	11	1911	608.	11	1943	19642.	9.78
5	14	1912	1100.	12	2007	15702.	10.69
7	8	1913	1560.	13	1966	14882.	11.61
6	12	1914	3140.	14	1995	14591.	12.52
7	3	1915	3130.	15	1965	13989.	13.44
7	11	1916	7740.	16	1994	13818.	14.35
4	3	1917	5240.	17	1975	13565.	15.27
3	31	1918	874.	18	1986	13492.	16.18
4	6	1919	680.	19	1993	13454.	17.09
3	28	1920	6200.	20	2005	12493.	18.01
4	6	1921	1970.	21	1984	12342.	18.92
4	11	1922	5200.	22	1962	11850.	19.84
6	29	1923	3960.	23	1947	11652.	20.75
4	30	1924	530.	24	1996	11208.	21.66
6	21	1925	940.	25	1951	11012.	22.58
3	24	1926	1600.	26	1972	9847.	23.49
3	19	1927	2650.	27	1950	9266.	24.41
3	28	1928	3840.	28	1998	9262.	25.32
3	20	1929	4440.	29	2003	9134.	26.23
3	17	1930	1340.	30	1945	8738.	27.15
4	3	1931	365.	31	1916	7740.	28.06
4	11	1932	875.	32	1946	7630.	28.98
4	5	1933	605.	33	1982	7300.	29.89
4	10	1934	323.	34	1944	7085.	30.80
3	20	1935	942.	35	1907	7000.	31.72
4	14	1936	1050.	36	1963	6643.	32.63
4	12	1937	1390.	37	1953	6633.	33.55
5	2	1938	1350.	38	1967	6519.	34.46
3	31	1939	3870.	39	2008	6443.	35.37
4	8	1940	1030.	40	1980	6393.	36.29
4	3	1941	1390.	41	1920	6200.	37.20
6	12	1942	5321.	42	2002	6045.	38.12
4	7	1943	19642.	43	2004	5976.	39.03
6	9	1944	7085.	44	1985	5690.	39.95
3	22	1945	8738.	45	1942	5321.	40.86
3	27	1946	7630.	46	1999	5290.	41.77
4	15	1947	11652.	47	1917	5240.	42.69
4	10	1948	4952.	48	2000	5224.	43.60
7	14	1949	3453.	49	1904	5220.	44.52

Table 18. Continued

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	FLOW CFS	RANK	WATER YEAR	FLOW CFS	MEDIAN PLOT POS
4	7	1950	9266.	50	1922	5200.	45.43
4	11	1951	11012.	51	1910	5000.	46.34
4	16	1952	21585.	52	1948	4952.	47.26
6	1	1953	6633.	53	1929	4440.	48.17
6	12	1954	2554.	54	1905	4250.	49.09
4	4	1955	2978.	55	1960	4189.	50.00
4	16	1956	3834.	56	1974	4137.	50.91
4	26	1957	3734.	57	1923	3960.	51.83
7	6	1958	2348.	58	1939	3870.	52.74
7	4	1959	1888.	59	1928	3840.	53.66
4	8	1960	4189.	60	1956	3834.	54.57
5	21	1961	958.	61	1991	3755.	55.48
5	29	1962	11850.	62	1957	3734.	56.40
6	14	1963	6643.	63	1976	3502.	57.31
4	18	1964	2618.	64	1949	3453.	58.23
4	15	1965	13989.	65	1987	3169.	59.14
3	22	1966	14882.	66	1914	3140.	60.05
6	19	1967	6519.	67	1915	3130.	60.97
4	30	1968	1186.	68	1906	3050.	61.88
4	15	1969	32978.	69	1955	2978.	62.80
6	18	1970	2513.	70	1971	2784.	63.71
3	22	1971	2784.	71	1992	2732.	64.63
3	24	1972	9847.	72	1927	2650.	65.54
3	19	1973	2184.	73	1964	2618.	66.45
4	14	1974	4137.	74	1908	2600.	67.37
7	5	1975	13565.	75	1954	2554.	68.28
3	30	1976	3502.	76	1970	2513.	69.20
5	5	1977	758.	77	1903	2450.	70.11
4	3	1978	22401.	78	1958	2348.	71.02
4	19	1979	21318.	79	1973	2184.	71.94
4	6	1980	6393.	80	1921	1970.	72.85
5	24	1981	1861.	81	1959	1888.	73.77
4	5	1982	7300.	82	1981	1861.	74.68
7	4	1983	1811.	83	1983	1811.	75.59
4	2	1984	12342.	84	1909	1780.	76.51
6	5	1985	5690.	85	1926	1600.	77.42
4	3	1986	13492.	86	1913	1560.	78.34
1	31	1987	3169.	87	1937	1390.	79.25
3	31	1988	1080.	88	1941	1390.	80.16
4	9	1989	22029.	89	1938	1350.	81.08
6	2	1990	975.	90	1930	1340.	81.99
7	7	1991	3755.	91	1968	1186.	82.91
6	19	1992	2732.	92	1902	1180.	83.82
4	6	1993	13454.	93	1912	1100.	84.73
4	1	1994	13818.	94	1988	1080.	85.65
3	22	1995	14591.	95	1936	1050.	86.56
4	16	1996	11208.	96	1940	1030.	87.48
4	11	1997	31768.	97	1990	975.	88.39
3	2	1998	9262.	98	1961	958.	89.31
6	10	1999	5290.	99	1935	942.	90.22
6	20	2000	5224.	100	1925	940.	91.13
4	15	2001	28829.	101	1932	875.	92.05
7	16	2002	6045.	102	1918	874.	92.96
6	30	2003	9134.	103	1977	758.	93.88
6	4	2004	5976.	104	1919	680.	94.79
6	18	2005	12493.	105	1911	608.	95.70
4	5	2006	26610.	106	1933	605.	96.62
6	8	2007	15702.	107	1924	530.	97.53
6	16	2008	6443.	108	1931	365.	98.45
3	28	2009	33753.	109	1934	323.	99.36

4.1.3 Regulated Condition

For the period from 1942 to 2009, recorded annual instantaneous peak flows were adopted. For the period prior to 1942, annual instantaneous peak flows were determined from another regression analysis of recorded mean daily peak flows vs. simulated mean daily flows for the period from 1942 to 2009. Once this relationship was established, recorded natural mean daily flows for 1902 to 1942 were read on the simulated mean daily scale to arrive at the regulated mean daily flow. **Figure 38** shows this regression relationship. **Figure 39** shows the regulated condition, peak, mean daily discharge-frequency curve superimposed with the natural, peak, mean daily, flow frequency curve. **Table 19** lists the regulated, annual, mean daily, peak flows.

Finally, to determine the regulated, annual, instantaneous peak flow, the regression relationship that was used in the natural condition computation and shown in **Figure 38,** was used to adjust the annual, mean daily, regulated, peak flows to annual, instantaneous, regulated peak flows. **Table 20** shows these flows, rank, and plotting position.

Once the period of record instantaneous peak flows were obtained they were plotted with the analytical, natural discharge-frequency curve. A graphical line was then drawn through the points.

To aid in drawing the upper portion of this curve, synthetic, 100-, 200-, and 500-yr events were routed through the upstream reservoirs and routed and combined with downstream flows. This was done for with- and without- reservoirs in place so that differences in natural and regulated conditions can be recorded and plotted. The events were based on balanced hydrographs derived from flood-volume frequency curves of inflows to the reservoirs and incremental local flows at downstream control points. These events were adopted from the Red River of the North Discharge-Frequency study for FIS (**reference 4**). It should be noted that these resulting, synthetic, hydrographs at Fargo do not reflect the corresponding frequencies on the Fargo discharge frequency curves. The natural condition, analytical, frequency curve was used to associate a representative frequency and the corresponding regulated flow was plotted at that same frequency. **Figure 40** shows the graphical, regulated, annual, instantaneous, peak discharge-frequency curve plotted with the analytical, natural, annual instantaneous, peak discharge-frequency curve.

Table 19 -Fargo Regulated Annual Mean Daily Peak Flows

-PLOTTING POSITIONS-FARGO USGS GAGE NO. 05054000 WITH RESERVOIRS

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	FLOW CFS	RANK	WATER YEAR	FLOW CFS	MEDIAN PLOT POS
4	11	1882	15868.	1	2009	29100.	.64
5	23	1902	947.	2	1997	27800.	1.55
4	6	1903	1967.	3	1969	24800.	2.47
6	28	1904	2272.	4	2001	20200.	3.38
5	17	1905	3412.	5	2006	19800.	4.30
4	9	1906	2449.	6	1989	18600.	5.21
6	17	1907	3549.	7	1979	17200.	6.12
6	13	1908	2088.	8	1978	17000.	7.04
5	30	1909	1429.	9	1952	16200.	7.95
3	20	1910	3774.	10	1943	16000.	8.87
4	11	1911	488.	11	1882	15868.	9.78
5	14	1912	883.	12	2007	13400.	10.69
7	8	1913	1172.	13	1975	13100.	11.61
6	12	1914	2457.	14	1965	11300.	12.52
7	2	1915	2497.	15	1994	11100.	13.44
7	11	1916	6198.	16	1966	10600.	14.35
4	3	1917	4175.	17	1995	10500.	15.27
3	30	1918	602.	18	1993	9940.	16.18
3	22	1919	506.	19	1996	9880.	17.09
3	27	1920	4914.	20	2005	9730.	18.01
4	6	1921	1582.	21	1962	9570.	18.92
4	11	1922	4175.	22	1984	9450.	19.84
6	29	1923	3179.	23	1947	9200.	20.75
4	30	1924	426.	24	1986	8600.	21.66
6	20	1925	711.	25	1998	8590.	22.58
3	24	1926	1285.	26	1951	7990.	23.49
3	19	1927	2128.	27	1950	7680.	24.41
3	28	1928	3083.	28	1945	7650.	25.32
3	20	1929	3565.	29	1972	7080.	26.23
3	17	1930	1076.	30	1953	6700.	27.15
4	3	1931	293.	31	2003	6680.	28.06
4	11	1932	697.	32	1916	6198.	28.98
4	5	1933	486.	33	1946	5880.	29.89
4	10	1934	259.	34	1982	5800.	30.80
3	19	1935	747.	35	1967	5760.	31.72
4	14	1936	843.	36	2004	5380.	32.63
4	12	1937	1044.	37	2000	5220.	33.55
5	2	1938	931.	38	1980	5180.	34.46
3	31	1939	2890.	39	1920	4914.	35.37
4	7	1940	779.	40	1963	4820.	36.29
4	3	1941	1116.	41	1999	4800.	37.20
6	11	1942	3330.	42	2008	4750.	38.12
4	7	1943	16000.	43	1985	4600.	39.03
6	10	1944	4120.	44	2002	4210.	39.95
3	22	1945	7650.	45	1922	4175.	40.86
3	27	1946	5880.	46	1917	4175.	41.77
4	14	1947	9200.	47	1944	4120.	42.69
4	10	1948	3340.	48	1974	4040.	43.60
7	12	1949	2600.	49	1956	3810.	44.52
4	7	1950	7680.	50	1910	3774.	45.43
4	11	1951	7990.	51	1960	3700.	46.34
4	15	1952	16200.	52	1929	3565.	47.26
6	1	1953	6700.	53	1907	3549.	48.17
7	4	1954	1830.	54	1905	3412.	49.09
4	4	1955	2600.	55	1948	3340.	50.00
4	16	1956	3810.	56	1942	3330.	50.91
4	24	1957	2520.	57	1923	3179.	51.83
7	6	1958	2240.	58	1928	3083.	52.74
7	9	1959	1150.	59	1976	3000.	53.66
4	8	1960	3700.	60	1987	2980.	54.57
6	9	1961	928.	61	1939	2890.	55.48

Table 19- Fargo Regulated Annual Mean Daily Peak Flows(cont.)

6	14	1962	9570.	62	1955	2600.	56.40
6	14	1963	4820.	63	1991	2600.	57.31
4	18	1964	2330.	64	1949	2600.	58.23
4	15	1965	11300.	65	1992	2570.	59.14
3	22	1966	10600.	66	1957	2520.	60.05
6	18	1967	5760.	67	1915	2497.	60.97
4	30	1968	780.	68	1914	2457.	61.88
4	14	1969	24800.	69	1906	2449.	62.80
6	18	1970	2390.	70	1970	2390.	63.71
7	6	1971	1850.	71	1964	2330.	64.63
3	24	1972	7080.	72	1904	2272.	65.54
3	15	1973	1830.	73	1958	2240.	66.45
4	14	1974	4040.	74	1927	2128.	67.37
7	4	1975	13100.	75	1908	2088.	68.28
3	30	1976	3000.	76	1903	1967.	69.20
5	5	1977	638.	77	1971	1850.	70.11
4	3	1978	17000.	78	1973	1830.	71.02
4	19	1979	17200.	79	1954	1830.	71.94
4	6	1980	5180.	80	1981	1710.	72.85
5	24	1981	1710.	81	1983	1620.	73.77
4	4	1982	5800.	82	1921	1582.	74.68
7	4	1983	1620.	83	1909	1429.	75.59
4	1	1984	9450.	84	1926	1285.	76.51
6	5	1985	4600.	85	1913	1172.	77.42
4	2	1986	8600.	86	1959	1150.	78.34
3	27	1987	2980.	87	1941	1116.	79.25
3	11	1988	924.	88	1930	1076.	80.16
4	9	1989	18600.	89	1937	1044.	81.08
6	2	1990	877.	90	1902	947.	81.99
7	6	1991	2600.	91	1938	931.	82.91
6	19	1992	2570.	92	1961	928.	83.82
4	6	1993	9940.	93	1988	924.	84.73
4	2	1994	11100.	94	1912	883.	85.65
3	22	1995	10500.	95	1990	877.	86.56
4	16	1996	9880.	96	1936	843.	87.48
4	17	1997	27800.	97	1968	780.	88.39
5	19	1998	8590.	98	1940	779.	89.31
3	21	1999	4800.	99	1935	747.	90.22
6	20	2000	5220.	100	1925	711.	91.13
4	14	2001	20200.	101	1932	697.	92.05
7	13	2002	4210.	102	1977	638.	92.96
6	30	2003	6680.	103	1918	602.	93.88
6	3	2004	5380.	104	1919	506.	94.79
6	18	2005	9730.	105	1911	488.	95.70
4	5	2006	19800.	106	1933	486.	96.62
6	8	2007	13400.	107	1924	426.	97.53
6	12	2008	4750.	108	1931	293.	98.45
3	28	2009	29100.	109	1934	259.	99.36

Table 20- Fargo Regulated Annual Instantaneous Peak Flows

-PLOTTING POSITIONS-FARGO USGS GAGE NO. 05054000 WITH RESERVOIRS

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	FLOW CFS	RANK	WATER YEAR	FLOW CFS	MEDIAN PLOT POS
4	11	1882	16058.	1	2009	29400.	.64
5	23	1902	959.	2	1997	28000.	1.55
4	6	1903	1991.	3	1969	25000.	2.47
6	28	1904	2299.	4	2001	20300.	3.38
5	17	1905	3453.	5	2006	19900.	4.30
4	9	1906	2478.	6	1989	18900.	5.21
6	17	1907	3591.	7	1978	17500.	6.12
6	13	1908	2113.	8	1979	17300.	7.04
5	30	1909	1446.	9	1952	16300.	7.95
3	20	1910	3819.	10	1882	16058.	8.87
4	11	1911	494.	11	1943	16000.	9.78
5	14	1912	894.	12	2007	13500.	10.69
7	8	1913	1186.	13	1975	13200.	11.61
6	12	1914	2486.	14	1965	11400.	12.52
7	2	1915	2527.	15	1994	11200.	13.44
7	11	1916	6273.	16	1995	11000.	14.35
4	3	1917	4225.	17	1966	10700.	15.27
3	30	1918	609.	18	1993	10100.	16.18
3	22	1919	512.	19	1996	9940.	17.09
3	27	1920	4973.	20	2005	9810.	18.01
4	6	1921	1601.	21	1962	9580.	18.92
4	11	1922	4225.	22	1984	9550.	19.84
6	29	1923	3218.	23	1947	9300.	20.75
4	30	1924	431.	24	1986	8640.	21.66
6	20	1925	719.	25	1998	8610.	22.58
3	24	1926	1300.	26	1951	8010.	23.49
3	19	1927	2153.	27	1950	7800.	24.41
3	28	1928	3120.	28	1945	7700.	25.32
3	20	1929	3608.	29	1972	7250.	26.23
3	17	1930	1089.	30	1953	6720.	27.15
4	3	1931	297.	31	2003	6710.	28.06
4	11	1932	705.	32	1916	6273.	28.98
4	5	1933	492.	33	1946	5970.	29.89
4	10	1934	262.	34	1982	5920.	30.80
3	19	1935	756.	35	1967	5900.	31.72
4	14	1936	853.	36	2000	5630.	32.63
4	12	1937	1056.	37	1980	5470.	33.55
5	2	1938	943.	38	2004	5430.	34.46
3	31	1939	2925.	39	1920	4973.	35.37
4	7	1940	788.	40	1963	4930.	36.29
4	3	1941	1129.	41	1999	4900.	37.20
6	11	1942	3380.	42	2008	4800.	38.12
4	7	1943	16000.	43	1985	4690.	39.03
6	10	1944	4150.	44	2002	4250.	39.95
3	22	1945	7700.	45	1917	4225.	40.86
3	27	1946	5970.	46	1922	4225.	41.77
4	15	1947	9300.	47	1974	4150.	42.69
4	10	1948	3390.	48	1944	4150.	43.60
7	12	1949	2660.	49	1960	3900.	44.52
4	7	1950	7800.	50	1956	3870.	45.43
4	11	1951	8010.	51	1910	3819.	46.34
4	16	1952	16300.	52	1929	3608.	47.26
6	1	1953	6720.	53	1907	3591.	48.17
7	4	1954	1920.	54	1905	3453.	49.09
4	4	1955	2760.	55	1948	3390.	50.00
4	16	1956	3870.	56	1942	3380.	50.91
4	24	1957	2540.	57	1987	3300.	51.83
7	6	1958	2280.	58	1923	3218.	52.74
7	8	1959	1250.	59	1976	3200.	53.66
4	8	1960	3900.	60	1928	3120.	54.57
6	9	1961	1020.	61	1939	2925.	55.48
6	14	1962	9580.	62	1955	2760.	56.40

Table 20-Fargo Regulated Annual Instantaneous Peak Flows(cont.)

6	14	1963	4930.	63	1949	2660.	57.31
4	18	1964	2400.	64	1991	2630.	58.23
4	15	1965	11400.	65	1992	2590.	59.14
3	22	1966	10700.	66	1957	2540.	60.05
6	19	1967	5900.	67	1915	2527.	60.97
4	30	1968	788.	68	1914	2486.	61.88
4	15	1969	25000.	69	1970	2480.	62.80
6	18	1970	2480.	70	1906	2478.	63.71
7	7	1971	1910.	71	1964	2400.	64.63
3	24	1972	7250.	72	1904	2299.	65.54
3	15	1973	1950.	73	1958	2280.	66.45
4	14	1974	4150.	74	1927	2153.	67.37
7	4	1975	13200.	75	1908	2113.	68.28
3	30	1976	3200.	76	1903	1991.	69.20
7	4	1977	878.	77	1973	1950.	70.11
4	2	1978	17500.	78	1954	1920.	71.02
4	19	1979	17300.	79	1971	1910.	71.94
4	5	1980	5470.	80	1983	1750.	72.85
5	24	1981	1710.	81	1981	1710.	73.77
4	4	1982	5920.	82	1921	1601.	74.68
7	4	1983	1750.	83	1909	1446.	75.59
4	1	1984	9550.	84	1926	1300.	76.51
6	5	1985	4690.	85	1959	1250.	77.42
4	2	1986	8640.	86	1990	1220.	78.34
3	27	1987	3300.	87	1913	1186.	79.25
3	11	1988	981.	88	1941	1129.	80.16
4	9	1989	18900.	89	1930	1089.	81.08
6	2	1990	1220.	90	1937	1056.	81.99
7	6	1991	2630.	91	1961	1020.	82.91
6	19	1992	2590.	92	1988	981.	83.82
4	5	1993	10100.	93	1902	959.	84.73
4	3	1994	11200.	94	1938	943.	85.65
3	22	1995	11000.	95	1912	894.	86.56
4	15	1996	9940.	96	1977	878.	87.48
4	17	1997	28000.	97	1936	853.	88.39
5	19	1998	8610.	98	1968	788.	89.31
3	22	1999	4900.	99	1940	788.	90.22
6	20	2000	5630.	100	1935	756.	91.13
4	14	2001	20300.	101	1925	719.	92.05
7	13	2002	4250.	102	1932	705.	92.96
6	30	2003	6710.	103	1918	609.	93.88
6	3	2004	5430.	104	1919	512.	94.79
6	18	2005	9810.	105	1911	494.	95.70
4	5	2006	19900.	106	1933	492.	96.62
6	8	2007	13500.	107	1924	431.	97.53
6	12	2008	4800.	108	1931	297.	98.45
3	28	2009	29400.	109	1934	262.	99.36

4.2 RED RIVER AT WAHPETON, ND

Development of discharge - probability distributions through the Breckenridge/Wahpeton study area are affected by the upstream flood control reservoirs at White Rock Dam and Orwell Dam, an upstream breakout flow area near County Ditch No. 55 and State Highway 127, and ice conditions in the form of either ice cover and/or ice jams on the Red River of the North. Analysis of the historical operation of the upstream reservoirs indicates that they have been regulated so as to not significantly contribute to peak flows at the Wahpeton gage. With the exception of the 1997 flood event, all peak flows from 1942 - 1996 are considered to be representative of the local drainage area (1,020 square miles) between the dams and the Wahpeton streamflow gage. To include the impacts on the frequency curve from upstream breakout flows, a HEC-RAS analysis ("Hydrologic Engineering Center - River Analysis System", (**reference 6**) was conducted to determine a split-flow relationship at the breakout area near County Ditch No. 55 and State Highway 127.

The annual instantaneous peak flow measured at Wahpeton in 1997 was 12,800 cfs on April 15. However, inspection of reservoir releases indicates that the maximum local peak flow at the gage was approximately 10,000 cfs. Breakout flows from the Bois de Sioux River across State Highway 127 were observed for the first time during the 1997 flood of record when a peak discharge of 2,200 cfs was estimated to have broken out of the Bois de Sioux River upstream of the Wahpeton gage. Without the existence of the breakout area, a peak flow as large as 15,000 cfs could have potentially been observed at the gaging station. A schematic of this breakout scenario can be seen in **Figure 6**.

Prior to the 1997 flood event, annual peak discharges observed at the Wahpeton gage for the entire period of record were unaffected by upstream reservoir releases and breakout flows across State Highway 127. Based upon streamflows measured at the Wahpeton gage and known outflows from White Rock Dam and Orwell Dam, the local peak flow for 1997 at Wahpeton occurred on April 6 and had an estimated discharge of 12,000 cfs (which includes estimated breakout flows at County Ditch No. 55/State Highway 127).

Because of the complexity due to reservoirs, breakout flows and ice conditions in developing frequency distributions within the study area, it was determined to initially establish a 0.2 percent exceedance frequency for discharge and stage that would serve to anchor the upper end of the frequency relationships. For flood events approaching the 0.2 percent exceedance frequency, it is assumed that all ice would be swept out and these large events would occur under open-water conditions. To obtain a reasonable maximum discharge for the 0.2 percent exceedance frequency, a graphical drainage area - discharge ratio method was employed using computed discharge - frequency relationships for gaging stations at Wahpeton with just local drainage area flow and Wahpeton with total area flow. To determine an upper limit value for the 0.2% event peak discharge, the total drainage area at Wahpeton/Breckenridge was assumed to be a maximum of 2,425 square miles, which includes the contributing drainage upstream of the reservoirs.

A peak discharge - frequency relationship at Wahpeton was established for the local contributing drainage area based on period of record flows at the Wahpeton streamflow gage. To reflect increases in flow for the larger floods due to reservoir releases, adjustments were then made to this local area frequency curve with consideration given to the upper limit of the previously determined 0.2% discharge. Breakout flows were then subtracted from this discharge - frequency curve based on a split flow analysis conducted for the breakout area.

In 2004 a diversion was built to divert a portion of the flow from the Otter Tail River around Breckenridge. Flows used in the Wahpeton discharge-frequency were included in the analysis. Flows from the breakout point upstream of Wahpeton on the Bois de Sioux were also initially included in development of a frequency-curve, but then this curve was adjusted to account for the breakout.

4.2.1 Unadjusted – Local Flow below Dams

Using an estimated local peak discharge of 12,000 cfs for the 1997 flood and 17,400 cfs for the 2009 flood, an annual instantaneous peak discharge - frequency curve was developed for the local drainage area of 1,020 square miles based on period of record flows from 1942 through 2009. Minor adjustment in flow values were also made for the years 1958, 1963, 1964, 1975, 1976, 1991, and 1996 for slight affects from reservoir releases (actually represented insignificant increases but adjustments were made for technical accuracy). **Table 21** lists the Wahpeton, annual, Instantaneous, peak flows for just the local area including breakout flows that occurred upstream.

Table 21-Wahpeton Unadjusted Local Peak Flows

-PLOTTING POSITIONS-

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	FLOW CFS	RANK	WATER YEAR	FLOW CFS	MEDIAN PLOT POS
0	0	1942	3280.	1	2009	17400.	1.02
0	0	1943	5000.	2	1997	12000.	2.49
0	0	1944	4360.	3	2006	10640.	3.95
0	0	1945	3910.	4	2007	10180.	5.41
0	0	1946	3110.	5	2001	10080.	6.87
0	0	1947	4610.	6	1969	9940.	8.33
0	0	1948	2300.	7	1989	8370.	9.80
0	0	1949	2290.	8	1952	7130.	11.26
0	0	1950	4190.	9	1979	7050.	12.72
0	0	1951	6090.	10	1995	6370.	14.18
0	0	1952	7130.	11	2005	6360.	15.64
0	0	1953	3150.	12	1978	6250.	17.11
0	0	1954	1860.	13	1986	6140.	18.57
0	0	1955	1150.	14	1951	6090.	20.03
0	0	1956	1980.	15	1993	6080.	21.49
0	0	1957	2290.	16	1965	5690.	22.95
0	0	1958	866.	17	1962	5650.	24.42
0	0	1959	1050.	18	1996	5400.	25.88
0	0	1960	2370.	19	1994	5000.	27.34
0	0	1961	548.	20	1943	5000.	28.80
0	0	1962	5650.	21	1966	4760.	30.26
0	0	1963	3830.	22	1984	4710.	31.73
0	0	1964	1700.	23	1947	4610.	33.19
0	0	1965	5690.	24	1944	4360.	34.65
0	0	1966	4760.	25	1998	4250.	36.11

Table 11- Wahpeton Unadjusted Local Peak Flows (cont.)

0	0	1967	2500.	26	1999	4220.	37.57
0	0	1968	708.	27	1950	4190.	39.04
0	0	1969	9940.	28	1945	3910.	40.50
0	0	1970	1450.	29	1975	3850.	41.96
0	0	1971	927.	30	1963	3830.	43.42
0	0	1972	3380.	31	2003	3800.	44.88
0	0	1973	1220.	32	1985	3690.	46.35
0	0	1974	1250.	33	2008	3530.	47.81
0	0	1975	3850.	34	1972	3380.	49.27
0	0	1976	2700.	35	2002	3350.	50.73
0	0	1977	526.	36	1942	3280.	52.19
0	0	1978	6250.	37	2004	3160.	53.65
0	0	1979	7050.	38	1953	3150.	55.12
0	0	1980	3100.	39	1982	3120.	56.58
0	0	1981	512.	40	1946	3110.	58.04
0	0	1982	3120.	41	1980	3100.	59.50
0	0	1983	880.	42	1991	2980.	60.96
0	0	1984	4710.	43	1976	2700.	62.43
0	0	1985	3690.	44	2000	2630.	63.89
0	0	1986	6140.	45	1967	2500.	65.35
0	0	1987	1770.	46	1960	2370.	66.81
0	0	1988	911.	47	1948	2300.	68.27
0	0	1989	8370.	48	1949	2290.	69.74
0	0	1990	900.	49	1957	2290.	71.20
0	0	1991	2980.	50	1992	2000.	72.66
0	0	1992	2000.	51	1956	1980.	74.12
0	0	1993	6080.	52	1954	1860.	75.58
0	0	1994	5000.	53	1987	1770.	77.05
0	0	1995	6370.	54	1964	1700.	78.51
0	0	1996	5400.	55	1970	1450.	79.97
0	0	1997	12000.	56	1974	1250.	81.43
0	0	1998	4250.	57	1973	1220.	82.89
0	0	1999	4220.	58	1955	1150.	84.36
0	0	2000	2630.	59	1959	1050.	85.82
0	0	2001	10080.	60	1971	927.	87.28
0	0	2002	3350.	61	1988	911.	88.74
0	0	2003	3800.	62	1990	900.	90.20
0	0	2004	3160.	63	1983	880.	91.67
0	0	2005	6360.	64	1958	866.	93.13
0	0	2006	10640.	65	1968	708.	94.59
0	0	2007	10180.	66	1961	548.	96.05
0	0	2008	3530.	67	1977	526.	97.51
0	0	2009	17400.	68	1981	512.	98.98

4.2.2 Adjusted – Two Station Comparison with Fargo

The two-station comparison method was then used for adjusting the frequency statistics of the local flow at the Wahpeton station on the basis of regression analysis with the longer natural flow record available at the Fargo gaging station. The mean logarithm was adjusted from 3.4793 to 3.3316 and the standard deviation was adjusted from 0.3444 to 0.4003. These statistics were based only on the 68 years of concurrent record.

The station skew of -0.4385, which was based on using the 2009 and 1997 floods as the largest discharge events since the historic flood of 1897, was weighted with the generalized skew of -0.2400 to produce the adopted skew of -0.3843. This discharge - frequency relationship (adjusted statistics) is shown on **Figure 41** and represents only the local drainage contributions. This distribution does not account for reductions in flow due to upstream breakouts and increases in flow from reservoir contributions which are known to occur for large flood events such as 2009 and 1997. **Table 22** shows the discharge-frequency values labeled as Natural w/o breakout.

Table 22-Wahpeton Discharge-Frequencies

LOCATION	DA	2-YR	5-YR	10-YR	20-YR	50-YR	100-YR	200-YR	500-YR	comment
Wahpeton	2,425	2,280	4,720	6,690	8,780	11,700	14,100	16,500	19,900	Wahpeton Natural w/o breakout
	1,020	2,280	4,720	6,690	8,780	11,700	15,515	20,411	27,628	Wahpeton w/dams w/o breakout
		2,280	4,720	6,690	8,550	10,950	13,300	16,000	19,600	Wahpeton w/dams w/breakout
	contributing drainage area						1,172	1,364	1,556	DA; ultimate = 2,425

4.2.3 With Total Contributing Drainage Area

To establish the discharge - frequency curve at Wahpeton with impacts from the upstream reservoirs, a general relations methodology of drainage area - peak discharge was employed. A logarithmic plot of drainage area versus discharge was established for flood events of several recurrence intervals based on adopted annual peak discharges for Wahpeton local drainage area flow and Wahpeton with total drainage area flow. Using a maximum contributing drainage area at Wahpeton of 2,425 square miles (maximum contributing drainage upstream of reservoirs), the logarithmic plot of drainage area - discharge was used to establish an upper limit boundary for the discharge - probability relationship at the Wahpeton gage. **Figure 42** shows the discharge-area graphical plot. **Figure 42** shows the upper boundary curve.

4.2.4 With 1997 & 2009 Events

The median plotting position value for the 2009 and 1997 peak flood events were used as a guide for graphically shaping the upper end of the discharge-frequency curve. The median plotting position value is 0.62 and 1.50 percent respectively, based on these floods being the largest known flood events since the historical flood of 1897. The 2009 and 1997 peak flood peaks values were plotted as 19,600 cfs and 15,000 cfs, respectively which represents the estimated total flow at Wahpeton without breakout flow impact. **Figure 43** shows the plotted 1997 and 2009 events.

4.2.5 Adjustments for Contributing Area above Dams

To further aid in defining the upper end of the frequency curve, increasingly larger drainage areas were used within the framework of the general relation's methodology so as to represent the increase in contributing drainage from those areas upstream of the reservoirs for progressively larger flood events. Flows downstream of Wahpeton originate primarily from the incremental local area downstream of the reservoirs. For higher frequency events the reservoirs contribute flow to the peaks downstream. The amount of this flow contribution was estimated based on the portion of drainage area that was not controlled by the reservoirs. An analysis was done in a previous study that determined the additional contributing area for each frequency (**reference 5**). These additional contributing drainage areas are listed in **Table 23**.

Table 23-Additional Contributing Drainage Area

	Contributing Drainage Area Computation			
Recurrence Interval	Area Below Reservoirs sq. mi.	Area Above Orwell sq. mi.	Area Above L. Traverse sq. mi.	Total Contributiong Area sq. mi.
Fargo				
2				3220
5	3220	10	0	3230
10	3220	47	0	3267
20	3220	102	0	3322
50	3220	142	0	3362
100	3220	157	0	3377
200	3220	172	170	3562
500	3220	187	348	3755
d/s Drain 53				
2	3165			3165
5	3165	10	0	3175
10	3165	47	0	3212
20	3165	102	0	3267
50	3165	142	0	3307
100	3165	157	0	3322
200	3165	172	170	3507
500	3165	187	348	3700
u/s Drain 53				
2	3135			3135
5	3135	10	0	3145
10	3135	47	0	3182
20	3135	102	0	3237
50	3135	142	0	3277
100	3135	157	0	3292
200	3135	172	170	3477
500	3135	187	348	3670
Wild Rice d/s				
2	3080			3080
5	3080	10	0	3090
10	3080	47	0	3127
20	3080	102	0	3182
50	3080	142	0	3222
100	3080	157	0	3237
200	3080	172	170	3422
500	3080	187	348	3615
Wild Rice u/s				
2	1440			1440
5	1440	10	0	1450
10	1440	47	0	1487
20	1440	102	0	1542
50	1440	142	0	1582
100	1440	157	0	1597
200	1440	172	170	1782
500	1440	187	348	1975
D/S Woverton				
2	1430			1430
5	1430	10	0	1440
10	1430	47	0	1477
20	1430	102	0	1532
50	1430	142	0	1572
100	1430	157	0	1587
200	1430	172	170	1772
500	1430	187	348	1965
u/s Woverton				
2	1325			1325
5	1325	10	0	1335
10	1325	47	0	1372
20	1325	102	0	1427
50	1325	142	0	1467
100	1325	157	0	1482
200	1325	172	170	1667
500	1325	187	348	1860
Hickson				
2	1310			1310
5	1310	10	0	1320
10	1310	47	0	1357
20	1310	102	0	1412
50	1310	142	0	1452
100	1310	157	0	1467
200	1310	172	170	1652
500	1310	187	348	1845
Wahpeton				
2	1020			1020
5	1020	10	0	1030
10	1020	47	0	1067
20	1020	102	0	1122
50	1020	142	0	1162
100	1020	157	0	1177
200	1020	172	170	1362
500	1020	187	348	1555

Flows for the 1-, 0.5-, and 0.2 percent chance of exceedance events were determined from the graphical plot of drainage area and discharge using the corresponding contributing drainage area shown in **Table 23**.

They were then plotted with the local flow discharge-frequency curve. The resulting discharge - frequency relationship for the Red River of the North at Wahpeton is shown on **Figure 43** and represents local drainage along with contributions from the upstream reservoir areas for the larger, less frequent floods. This frequency curve does not include reductions due to the breakout flow area. These discharge-frequencies are also listed in **Table 22**.

4.2.6 Adjustments for Upstream Breakout Flow

To include the impacts on the frequency curve from upstream breakout flows, an HEC-RAS analysis ("Hydrologic Engineering Center - River Analysis System", **(reference 6)** was conducted to determine a split-flow relationship at the breakout area near County Ditch No. 55 and State Highway 127. This curve is shown in **Figure 44**. Results of this analysis were used to apply holdouts to the previously developed discharge - frequency curve to account for the breakout flows that never reach the Wahpeton gage for the larger flood events. The resulting annual peak discharge - frequency relationship is shown as the lower curve in **Figure 43** and represents local drainage along with contributions from the upstream reservoirs and reduction impacts from the upstream breakout area. For the purpose of performing risk-based analysis, the discharge - frequency relationship at Wahpeton was extrapolated for determining flow values for the 0.10% and 0.15% frequencies. **Table 22** lists the discharge-frequency for Wahpeton with all the adjustments.

4.3 RED RIVER AT HICKSON

The USGS gage for the Red River at Hickson, has a relatively short period of record from 1976 to the present. To determine a discharge frequency relationship for this station a graphical relationship is required because of the regulation effects from the two upstream reservoirs.

The record at Hickson was back-extended using the Hec-5 output for regulated flows from 1942 to 1975 and then graphically correlated to the Fargo gage for the full period of record at Fargo. In this way the discharge-frequency relationship would reflect a homogeneous set with respect to the hydro-climatic period at Fargo. The Hickson event flows were assigned plotting positions equivalent to Fargo event plotting positions for the concurrent period and corresponding rank. **Table 24** shows this array more clearly. **Figure 45** shows the resulting graphical plot. This curve was updated in **Appeudix A-2** using Weibull plotting positions.

Table 24- Hickson Graphical Correlation with Fargo

Fago Year	Fargo Inst Pks cfs	Median PP	Hickson DATE	Adopted Inst. Pks cfs
2009	29,400	0.55	26-Mar-2009	22,600
1997	28,000	1.32	3-Apr-2006	14,400
1969	25,000	2.1	14-Apr-1997	13,300
2001	20,300	2.88	7-Apr-1989	12,900
1897	20,073	3.66		
2006	19,900	[illegible]	[illegible]	[illegible]
1989	18,900	[illegible]	[illegible]	[illegible]
1978	17,500	[illegible]	[illegible]	[illegible]
1979	17,300	7.[illegible]	[illegible]	[illegible]
1952	16,300	[illegible]	[illegible]	[illegible]
1882	16,058	8.94		
1943	16,000	9.85	2-Apr-1978	9,200
2007	13,500	10.77	20-Mar-1995	8,000
1975	13,200	11.68	13-Jun-1962	7,466
1965	11,400	12.59	9-Apr-1951	7,445
1994	11,200	13.51	16-Jun-2005	7,090
1995	11,000	14.42	9-Apr-1943	7,014
1966	10,700	[illegible]	[illegible]	[illegible]
1993	10,100	[illegible]	[illegible]	[illegible]
1996	9,940	[illegible]	[illegible]	[illegible]
2005	9,810	[illegible]	[illegible]	[illegible]
1962	9,580	[illegible]	[illegible]	[illegible]
1984	9,550	[illegible]	[illegible]	[illegible]
1947	9,300	20.82	15-Apr-1947	6,074
1986	8,640	21.73	12-May-1950	5,476
1998	8,610	22.64	8-Jun-1944	5,364
1951	8,010	23.56	31-Mar-1984	5,100
1950	7,800	24.47	6-Jul-1975	4,936
1945	7,700	25.38	20-Mar-1945	4,845
1972	7,250	26.3	13-Jun-1963	4,746
1953	6,720	27.21	28-Feb-1998	4,590
2003	6,710	28.13	29-Jun-2003	4,390
1916	6,273	29.04		
1946	5,970	29.95	22-Mar-1972	4,215
1982	5,920	30.87	4-Apr-1982	4,200
1967	5,900	31.78	24-Jun-1953	4,014
2000	5,630	32.69	10-Jun-1942	4,002
1980	5,470	33.61	4-May-2006	3,910
2004	5,430	34.52	24-Mar-1946	3,786
1920	4,973	35.43		
1963	4,930	[illegible]	[illegible]	[illegible]
1999	4,900	[illegible]	[illegible]	[illegible]
2008	4,800	[illegible]	[illegible]	[illegible]
1985	4,690	[illegible]	[illegible]	[illegible]
2002	4,250	[illegible]	[illegible]	[illegible]
1917	4,225	40.92		
1922	4,225	41.83		
1944	4,150	42.74	27-Sep-2004	3,140
1974	4,150	43.66	9-Apr-1948	3,013
1960	3,900	44.57	9-Apr-1960	2,947
1956	3,870	45.48	5-Jul-1991	2,620
1910	3,819	46.4		
1929	3,608	47.31		
1907	3,591	48.23		
1905	3,453	49.14		
1948	3,390	50.05	24-Apr-1957	2,814
1942	3,380	50.97	12-Jul-1949	2,781
1987	3,300	51.88	11-Mar-2000	2,750
1923	3,218	52.79		
1976	3,200	53.71	16-Apr-1956	2,501
1928	3,120	54.62		
1939	2,925	55.53		
1955	2,760	56.45	31-Mar-1976	2,500
1949	2,660	57.36	26-Mar-1987	2,460
1991	2,630	58.27	11-Jun-1954	2,392
1992	2,590	59.19	8-May-1964	2,050
1957	2,540	60.1	11-Apr-1970	1,782
1915	2,527	61.02		
1914	2,486	61.93		
1970	2,480	62.84	10-Mar-1992	1,750
1906	2,478	63.76		
1964	2,400	64.67	6-Jun-1974	1,700
1904	2,299	65.58		
1958	2,280	66.5	18-Mar-1973	1,630
1927	2,153	67.41		
1908	2,113	68.32		
1903	1,991	69.24		
1973	1,950	70.15	5-Apr-1955	1,403
1954	1,920	71.07	29-May-1959	1,318
1971	1,910	71.98	18-Apr-1958	1,149
1983	1,750	72.89	21-Mar-1971	1,145
1981	1,710	73.81	20-May-1968	955
1921	1,601	74.72		
1909	1,446	75.63		
1926	1,300	76.55		
1959	1,250	77.46	2-Apr-1990	857
1990	1,220	78.37	30-Mar-1988	826
1913	1,186	79.29		
1941	1,129	80.2		
1930	1,089	81.12		
1937	1,056	82.03		
1961	1,020	82.94	19-Mar-1983	824
1988	981	83.86	11-Jun-1961	719
1902	959	84.77		
1938	943	85.68		
1912	894	86.6		
1977	878	87.51	4-Aug-1981	544
1936	853	88.42		
1940	788	89.34		
1968	788	90.25	27-Jun-1977	408
1935	756	91.16		
1925	719	92.08		
1932	705	92.99		
1918	609	93.91		
1919	512	94.82		
1911	494	95.73		
1933	492	96.65		
1924	431	97.56		
1931	297	98.47		
1934	262	99.39		

Concurrent Hickson Flow

Non-concurrent Fargo Flow

4.4 WILD RICE RIVER, ND

4.4.1 Coincident Wild Rice, ND with Red River Peaks

Coincidental flows from the Wild Rice River tributary for corresponding peak flows on the Red River were derived from flows at the Abercrombie gage just upstream of the confluence of the Wild Rice River and Red River. To estimate the coincident flows, travel time from the confluence to the Fargo gage was estimated to be one day. Similarly, the travel time from the Abercrombie gage to the confluence with the Red River was also estimated to be one day. Therefore coincidental contribution of flow from the Wild Rice tributary was estimated by recording the flow at the Abercrombie gage that corresponded to a date of two days prior to the peak flow at the Fargo gage. **Table 25** lists the coincident data flow series and **Figure 46** shows the discharge-frequency curve. This curve was updated in **Appendix A-2** using Weibull plotting positions. **Table 26** lists the discharge-frequency flows.

4.4.2 Coincident Red River with Wild Rice, ND Peaks

Coincidental flows from the Red River for corresponding peak flows on the Wild Rice River were derived from flows at the Fargo gage just downstream of the confluence of the Wild Rice River and Red River. To estimate the coincident flows, travel time from the confluence to the Fargo gage was estimated to be one day. Similarly, the travel time from the Abercrombie gage to the confluence with the Red River was also estimated to be one day. Therefore coincidental contribution of flow from the Red River was estimated by recording the flow at the Fargo gage that corresponded to a date of two days after the peak flow at the Abercrombie gage. **Table 27** lists the coincident data flow series and **Figure 47** shows the discharge-frequency curve. A graphical curve was drawn through the plotted points to arrive at the adopted discharge-frequencies. **Table 26** lists the discharge-frequency flows.

Table 25- Wild Rice River @ Abercrombie, Coincidental Flows

-PLOTTING POSITIONS-abercoin

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	FLOW CFS	RANK	WATER YEAR	FLOW CFS	MEDIAN PLOT POS
0	0	1933	55.	1	2009	13641.	.90
0	0	1934	15.	2	1969	9250.	2.20
0	0	1935	513.	3	2006	9100.	3.49
0	0	1936	93.	4	2001	8040.	4.78
0	0	1937	540.	5	1997	7460.	6.07
0	0	1938	36.	6	1989	6770.	7.36
0	0	1939	550.	7	2007	5900.	8.66
0	0	1940	170.	8	1979	5800.	9.95
0	0	1941	324.	9	1952	5300.	11.24
0	0	1942	420.	10	1978	4850.	12.53
0	0	1943	4570.	11	1943	4570.	13.82
0	0	1944	790.	12	1993	3480.	15.12
0	0	1945	2800.	13	1984	2950.	16.41
0	0	1946	2250.	14	1966	2820.	17.70
0	0	1947	2450.	15	1945	2800.	18.99
0	0	1948	360.	16	1995	2800.	20.28
0	0	1949	487.	17	1965	2790.	21.58
0	0	1950	2190.	18	1962	2740.	22.87
0	0	1951	1750.	19	1998	2640.	24.16
0	0	1952	5300.	20	1947	2450.	25.45
0	0	1953	2160.	21	1996	2330.	26.74
0	0	1954	3.	22	1946	2250.	28.04
0	0	1955	520.	23	1950	2190.	29.33
0	0	1956	630.	24	2004	2170.	30.62
0	0	1957	242.	25	1975	2160.	31.91
0	0	1958	25.	26	1953	2160.	33.20
0	0	1959	7.	27	1986	2140.	34.50
0	0	1960	250.	28	2003	2100.	35.79
0	0	1961	2.	29	1994	2080.	37.08
0	0	1962	2740.	30	1967	1980.	38.37
0	0	1963	940.	31	1951	1750.	39.66
0	0	1964	157.	32	2005	1620.	40.96
0	0	1965	2790.	33	1972	1580.	42.25
0	0	1966	2820.	34	1982	1470.	43.54
0	0	1967	1980.	35	1999	1400.	44.83
0	0	1968	114.	36	1980	1300.	46.12
0	0	1969	9250.	37	1985	1060.	47.42
0	0	1970	241.	38	2008	1000.	48.71
0	0	1971	348.	39	1963	940.	50.00
0	0	1972	1580.	40	1944	790.	51.29
0	0	1973	88.	41	1976	630.	52.58
0	0	1974	217.	42	1956	630.	53.88
0	0	1975	2160.	43	1939	550.	55.17
0	0	1976	630.	44	1937	540.	56.46
0	0	1977	4.	45	1955	520.	57.75
0	0	1978	4850.	46	1935	513.	59.04
0	0	1979	5800.	47	1949	487.	60.34
0	0	1980	1300.	48	1992	461.	61.63
0	0	1981	1.	49	1942	420.	62.92
0	0	1982	1470.	50	1948	360.	64.21
0	0	1983	1.	51	2002	356.	65.50
0	0	1984	2950.	52	1971	348.	66.80
0	0	1985	1060.	53	1941	324.	68.09
0	0	1986	2140.	54	1960	250.	69.38
0	0	1987	175.	55	1957	242.	70.67
0	0	1988	15.	56	1970	241.	71.96
0	0	1989	6770.	57	1974	217.	73.26
0	0	1990	2.	58	1987	175.	74.55
0	0	1991	63.	59	1940	170.	75.84

Table 25- Wild Rice River @ Abercrombie, Coincidental Flows (cont.)

```
*   0   0  1992      461.  *    60   1964        157.     77.13  *
*   0   0  1993     3480.  *    61   2000        134.     78.42  *
*   0   0  1994     2080.  *    62   1968        114.     79.72  *
*   0   0  1995     2800.  *    63   1936         93.     81.01  *
*   0   0  1996     2330.  *    64   1973         88.     82.30  *
*   0   0  1997     7460.  *    65   1991         63.     83.59  *
*   0   0  1998     2640.  *    66   1933         55.     84.88  *
*   0   0  1999     1400.  *    67   1938         36.     86.18  *
*   0   0  2000      134.  *    68   1958         25.     87.47  *
*   0   0  2001     8040.  *    69   1988         15.     88.76  *
*   0   0  2002      356.  *    70   1934         15.     90.05  *
*   0   0  2003     2100.  *    71   1959          7.     91.34  *
*   0   0  2004     2170.  *    72   1977          4.     92.64  *
*   0   0  2005     1620.  *    73   1954          3.     93.93  *
*   0   0  2006     9100.  *    74   1990          2.     95.22  *
*   0   0  2007     5900.  *    75   1961          2.     96.51  *
*   0   0  2008     1000.  *    76   1981          1.     97.80  *
*   0   0  2009    13641.  *    77   1983          1.     99.10  *
*****************************************************************
```

Table 26- Coincident Wild Rice River Discharge-Frequencies

Exceedence Frequency Percent	Red flow coincident to Wild Rice Peak, cfs	Abercrombie Wild Rice Peak, cfs	Wild Rice confluence Peak,cfs	Wild Rice coincident to Red Peak, cfs	Red Peak, cfs
0.2	51,000	28,300	31,107	17,998	52,998
0.5	38,000	21,700	23,932	14,999	38,999
1	29,000	17,200	19,016	13,496	29,998
2	25,000	13,200	14,639	11,698	25,499
5	18,500	8,730	9,728	8,399	18,999
10	14,000	5,890	6,593	5,899	14,499
20	9,500	3,550	3,996	3,700	9,600
50	3,500	1,220	1,388	948	3,499

Table 27- Red River @ Wild Rice, ND Confluence, Coincidental Flows

-PLOTTING POSITIONS-RedConcidental

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	FLOW CFS	RANK	WATER YEAR	FLOW CFS	MEDIAN PLOT POS
0	0	1933	26.	1	2009	27600.	.90
0	0	1934	323.	2	1997	25800.	2.20
0	0	1935	930.	3	1969	24800.	3.49
0	0	1936	695.	4	2006	19800.	4.78
0	0	1937	1300.	5	1989	17600.	6.07
0	0	1938	502.	6	2001	17600.	7.36
0	0	1939	2800.	7	1978	16800.	8.66
0	0	1940	795.	8	1979	16500.	9.95
0	0	1941	1120.	9	1952	16200.	11.24
0	0	1942	2900.	10	1943	14000.	12.53
0	0	1943	14000.	11	2007	13400.	13.82
0	0	1944	3740.	12	1975	11600.	15.12
0	0	1945	7650.	13	1965	11300.	16.41
0	0	1946	5880.	14	1966	10600.	17.70
0	0	1947	9150.	15	1995	10000.	18.99
0	0	1948	1940.	16	1984	9450.	20.28
0	0	1949	1750.	17	1947	9150.	21.58
0	0	1950	7260.	18	1993	9070.	22.87
0	0	1951	7150.	19	1996	9020.	24.16
0	0	1952	16200.	20	1998	8440.	25.45
0	0	1953	6700.	21	1962	8160.	26.74
0	0	1954	1770.	22	2005	7940.	28.04
0	0	1955	2600.	23	1986	7840.	29.33
0	0	1956	3600.	24	1945	7650.	30.62
0	0	1957	2050.	25	1950	7260.	31.91
0	0	1958	925.	26	1951	7150.	33.20
0	0	1959	907.	27	1953	6700.	34.50
0	0	1960	3150.	28	2003	6500.	35.79
0	0	1961	488.	29	1972	6100.	37.08
0	0	1962	8160.	30	1946	5880.	38.37
0	0	1963	3800.	31	1982	5800.	39.66
0	0	1964	1860.	32	1967	5220.	40.96
0	0	1965	11300.	33	2004	5030.	42.25
0	0	1966	10600.	34	1999	4600.	43.54
0	0	1967	5220.	35	1980	4200.	44.83
0	0	1968	740.	36	1994	4090.	46.12
0	0	1969	24800.	37	1985	3960.	47.42
0	0	1970	1750.	38	1963	3800.	48.71
0	0	1971	1750.	39	1944	3740.	50.00
0	0	1972	6100.	40	2002	3700.	51.29
0	0	1973	1460.	41	1956	3600.	52.58
0	0	1974	3390.	42	1974	3390.	53.88
0	0	1975	11600.	43	1960	3150.	55.17
0	0	1976	2540.	44	1942	2900.	56.46
0	0	1977	389.	45	1939	2800.	57.75
0	0	1978	16800.	46	1955	2600.	59.04
0	0	1979	16500.	47	1976	2540.	60.34
0	0	1980	4200.	48	2008	2520.	61.63
0	0	1981	308.	49	1991	2310.	62.92
0	0	1982	5800.	50	1992	2120.	64.21
0	0	1983	1040.	51	1957	2050.	65.50
0	0	1984	9450.	52	2000	2010.	66.80
0	0	1985	3960.	53	1948	1940.	68.09
0	0	1986	7840.	54	1964	1860.	69.38
0	0	1987	1800.	55	1987	1800.	70.67
0	0	1988	831.	56	1954	1770.	71.96
0	0	1989	17600.	57	1970	1750.	73.26
0	0	1990	750.	58	1949	1750.	74.55
0	0	1991	2310.	59	1971	1750.	75.84
0	0	1992	2120.	60	1973	1460.	77.13
0	0	1993	9070.	61	1937	1300.	78.42
0	0	1994	4090.	62	1941	1120.	79.72

Table 27 Red River @ Wild Rice, ND Confluence, Coincidental Flows (cont.)

*	0	0	1995	10000.	*	63	1983	1040.	81.01	*
*	0	0	1996	9020.	*	64	1935	930.	82.30	*
*	0	0	1997	25800.	*	65	1958	925.	83.59	*
*	0	0	1998	8440.	*	66	1959	907.	84.88	*
*	0	0	1999	4600.	*	67	1988	831.	86.18	*
*	0	0	2000	2010.	*	68	1940	795.	87.47	*
*	0	0	2001	17600.	*	69	1990	750.	88.76	*
*	0	0	2002	3700.	*	70	1968	740.	90.05	*
*	0	0	2003	6500.	*	71	1936	695.	91.34	*
*	0	0	2004	5030.	*	72	1938	502.	92.64	*
*	0	0	2005	7940.	*	73	1961	488.	93.93	*
*	0	0	2006	19800.	*	74	1977	389.	95.22	*
*	0	0	2007	13400.	*	75	1934	323.	96.51	*
*	0	0	2008	2520.	*	76	1981	308.	97.80	*
*	0	0	2009	27600.	*	77	1933	26.	99.10	*

****

4.5 RED RIVER AT HALSTAD

To develop the instantaneous peak discharge-frequency relationship for Halstad, a two station comparison was done with the 70 years of record at Halstad and the 184 years of historic record at Grand Forks. The correlation between them produced a determination coefficient of 0.86. The effects of the reservoirs diminish considerably downstream of Fargo, ND due to increasing incremental drainage area. Therefore, flow-frequency analysis for stations downstream of Fargo, ND can be considered the same for both the regulated and the unregulated condition. Halstad and Grand Forks are analytical curves based on Log-Pearson Type III. **Figure 48** shows the Halstad discharge-frequency curve before adjustment and **Figure 49** shows the curve after adjustment.

4.6 RED RIVER AT GRAND FORKS

The Grand Forks USGS gaging station is the long-term station on the Red River below the Canadian border. The effects of the reservoirs diminish considerably downstream of Fargo, ND due to increasing incremental drainage area. Therefore, flow-frequency analysis for stations downstream of Fargo, ND can be considered the same for both the regulated and the unregulated condition. The annual instantaneous peak discharge - frequency curve for the Red River of the North at Grand Forks was based upon period of record flows available at the Grand Forks continuous streamflow gaging station. Observed streamflows from 1882 through 2009 along with the historic flood values for 1826, 1852 and 1861 were used within computer program HEC-FFA "Flood Frequency Analysis" which incorporates techniques consistent with Bulletin 17B "Guidelines for Determining Flood Frequency Analysis". The computed probability discharge-frequency curve is shown on **Figure 50** and is based on 128 systematic events with a historic period equal to 184 years.

4.7 RED RIVER REACH BETWEEN WAHPETON AND GRAND FORKS

Discharge-frequencies for the reach between the Wahpeton and Fargo gages were determined by interpolating between the adopted discharge-frequencies at the Fargo and Wahpeton gages using a drainage area ratio. For the reach between Fargo and Hickson, flows were varied only at the locations upstream and downstream of the Wild Rice River, ND based on its corresponding coincidental flow. Drainage areas used in the interpolation for designated key stations on the Red River between Wahpeton and Fargo varied based on contributing drainage area as described in Section 4.2 of this report. The additional contributing drainage areas listed in **Table 23** were added to the incremental local area downstream of the reservoirs to arrive at the total drainage used in the drainage area ratio interpolation.

Frequency flows were estimated between Fargo and Halstad by interpolating between the discharge-frequency curves adopted for Fargo and Halstad using a drainage area ratio raised to an exponent. Interpolation also incorporates the coincidental flow-frequency at the mouth of the Sheyenne River, Wild Rice River-MN and the Buffalo River. Coincidental flows from significant tributaries with the exception of the Sheyenne River were included. Flows upstream and downstream of the Sheyenne River were based on the generalized exponent. Flow-Frequency Curves are fixed at Fargo, Halstad, and at the mouth of the tributaries. Exponents are determined by using the goal seek function in Microsoft Excel to modify the drainage area ratio exponents until they generate flows at ungaged locations of interest that when combined with adopted coincidental tributary inflows and upstream flow-frequency curve inflows would generate the adopted downstream flow-frequency curve. The adopted exponents are displayed in **Table 28**.

Table 28-Drainage Area Exponent for Red River Reach between Fargo and Halstad

	2-YR	5-YR	10-YR	20-YR	50-YR	100-YR	200-YR	500-YR
n	0.698	0.380	0.331	0.370	0.415	0.478	0.401	0.316

The resulting summary of discharge-frequencies for the designated locations along the Red River is shown in **Table 29**. **Figure 51** displays the adopted discharge-frequency curves for designated locations on the Red River. It also incorporated the coincidental flow-frequency from the Wild Rice River, ND, Wild Rice River, MN, and the Buffalo River.

Table 29- Summary of Discharge-Frequencies

LOCATION	Drainage Area sq. mi.	DISCHARGES in cfs Recurrence Interval 2-YR	5-YR	10-YR	20-YR	50-YR	100-YR	200-YR	500-YR
Grand Forks	20,015	17,000	35,300	50,500	67,200	91,600	112,000	134,000	165,000
u/s Red Lake	16,215	11,090	24,600	36,100	48,800	67,500	83,700	100,000	124,000
Halstad	13,775	9,850	20,700	29,800	39,900	54,700	67,000	80,300	99,400
d/s Wild Rice, MN	13735	9,830	20,677	29,771	39,857	54,634	66,907	80,206	99,309
Wild Rice River, MN coincidental	1650	2,348	4,650	6,395	8,162	10,529	12,335	14,147	16,544
u/s Wild Rice, MN	12085	7,482	16,027	23,376	31,695	44,105	54,572	66,059	82,765
d/s Elm	12055	7,469	16,012	23,357	31,666	44,060	54,507	65,994	82,700
u/s Elm	11655	7,295	15,808	23,097	31,274	43,447	53,635	65,106	81,823
d/s Buffalo	11305	7,141	15,626	22,865	30,923	42,901	52,860	64,314	81,038
Buffalo River coincidental	1190	1,096	2,701	4,073	5,550	7,623	9,256	10,928	13,174
U/S Buffalo	10115	6,045	12,925	18,792	25,373	35,278	43,603	53,386	67,864
d/s sheyenne	9905	5,958	12,822	18,662	25,177	34,973	43,168	52,939	67,416
u/s Sheyenne	5055	3,724	9,930	14,933	19,635	26,458	31,302	40,416	54,510
Fargo	3,220	3,500	9,600	14,500	19,000	25,500	30,000	39,000	53,000
d/s Drain 53	3,165	3,500	9,600	14,500	19,000	25,499	29,999	38,999	52,999
u/s Drain 53	3,135	3,500	9,600	14,500	19,000	25,499	29,999	38,999	52,999
d/s Wild Rice	3,080	3,499	9,600	14,499	18,999	25,499	29,998	38,999	52,998
Wild Rice River coincidental	1,640	948	3,700	5,899	8,399	11,698	13,496	14,999	17,998
u/s Wild Rice	1,440	2,551	5,900	8,600	10,600	13,801	16,502	24,000	35,000
d/s Wolverton	1,430	2,551	5,900	8,600	10,600	13,801	16,502	24,000	35,000
u/s Wolverton	1,325	2,550	5,900	8,600	10,600	13,800	16,500	24,000	35,000
Hickson	1,310	2,550	5,900	8,600	10,600	13,800	16,500	24,000	35,000
Wahpeton	1,020	2,280	4,720	6,690	8,550	10,950	13,300	16,000	19,600
tributary									

5. HEC-RAS MODEL CALIBRATION & VERIFICATION

The 2009 event was chosen for calibration of the unsteady RAS model and the 2006 and 1997 events were chosen for verification. Actual gaged flows for these events were used where possible. For the significant un-gaged locations, estimates were made by drainage area ratio transfer or general relations.

For locations where flows were not gaged or available, the HEC-5 model was employed to route and combine with local area flows to configure the hydrographs. The HEC-5 model schematics were presented in this report as **Figure 3** and **Figure 4.** **Figure 52** through **Figure 57** show the simulated hydrographs compared to measured USGS flows. The measured USGS flows for the 2009 event are provisional. The Sheyenne River at Harwood and the Red River at Halstad were the selected stations used for comparison. The straddle-stagger method was used on a daily time interval. Each event had unique routing parameters.

The 2006 and 2009 events on the Maple River were derived from the USGS gage(0506000) Maple River near Mapleton. This gage includes flow that breaks out from the Sheyenne. However, since the 2009 event is provisional data, estimates for breakout flow in 2009 were based on the North Central River Forecast Center simulations. For the 1997 event, flows were based on USGS gage(05060100), Maple River below Mapleton, and do not include an estimate for breakout flows.

The Hec-5 model used in the analysis to synthesize "without dams" flows at Fargo used the Straddle-Stagger routing method. The parameters were based on previous studies done on the Red, most notably, "Volume I, Timing Analysis" for the Technical Resource Service, Red River of the North **(reference 8)**. **Table 30** lists the parameter values for each reach.

Table 30- Hec-5 Reach Routing Parameters

REACH	STRADDLE	STAGGER
Lake Traverse to Wahpeton	3	1
Orwell to Wahpeton	3	1
Wahpeton to Hickson	5	2
Hickson to Fargo	3	1
Abercrombie to Fargo	5	2

6. BALANCED HYDROGRPAHS

Balanced hydrographs for the 500-, 100-, 50-, and 10-yr events were determined at all pertinent computation points within the study area in support of the unsteady Ras model. To develop these hydrographs, flood volume frequency relationships were developed for each gaged station on the Red River. These are referred to as a direct analysis.

Un-gaged stations were derived by assuming the same in flow volume for each duration as at the most hydrologically similar gaged station. Volume durations used to configure the hydrographs were the 1-day, 3-day, 7-day, 15-day, and 30-day values. Once these durations were estimated, they were input to the HEC-1 model **(reference 7)** to configure a hydrograph that reflects these volumes per duration, patterned after the 2006 event hydrograph.

The spring 2006 flood event was selected as the pattern event for all balanced hydrographs developed for the Fargo-Moorhead Metro Study. This is consistent with the methodology used for the Wild Rice Study, ND, which also uses 2006 as the pattern event. At the time that hydrologists began work on the Fargo Moorhead Metro Study the USGS discharge measurements associated with 2009 spring flood event were still listed as estimates and the 2010 spring flood had not yet occurred. With 2009 and 2010 data unavailable, the next largest event in terms of peak magnitude and volume was 1997. In 1997 spring snowmelt was interrupted by a blizzard. The blizzard caused runoff to recess for a week before resuming. As a result of atypical hydro meteorological conditions, the 1997 event could not be used as a pattern event. The 2006 event was deemed to be most representative of a typical flood event in the Red River Basin.

Tributaries that presented significant flows required coincidental balanced hydrographs as flow boundary conditions in the unsteady HEC-RAS model. The coincident flow volumes were anchored off the instantaneous peak, coincident, discharge-frequencies. The 1-day duration was determined by correlation of mean daily peak flows with instantaneous peak flows at the representative gage on the tributary. This relation was assumed to also apply between the coincident, instantaneous peak, flow-frequencies and the coincident, mean daily peak, flow-frequencies. The same proportional change in flow volumes for each duration was assumed to be the same for the coincidental flow volumes as the gaged flow volumes.

All balanced hydrographs were smoothed using graphical capabilities within DSS-Vue.

6.1 GAGED LOCATIONS

Flood volume frequency curves were developed for the main stem gaged flows at Wahpeton, Hickson, Fargo, and Halstad on the Red River. Flood volume frequencies were also required for tributary gages. These were: Buffalo River at Dilworth, Wild Rice River-MN at Hendrum, Wild Rice River-ND at Abercrombie, and Sheyenne River at West Fargo. The analysis first used the actual recorded flows. These curves were used to estimate the proportional change in volumes for each duration and for the full range of frequencies for the adopted flows with their corresponding adjustments. **Figure 58** to **Figure 64** shows these relationships for the recorded flows before adjustments.

Table 31 shows these locations and method of development. Direct refers to those stations on the Red River. Coincidental refers to tributary flows that would coincide with the peak flows on the Red River. Each station used its respective peak flow frequency; however, the durations were proportioned from the 1-day duration as an adopted station analysis of recorded flows. This is true for the main stem as well as tributary flows since adopted main stem discharge frequencies were adjusted in all cases.

6.2 UNGAGED LOCATIONS

Flood volume frequency relations were developed at significant computation points using information from those developed at the gaged locations. **Table 31** references which stations they would be. The volume duration was developed in the same manner as for gaged flow volume frequencies. Instantaneous peak discharge frequency was determined by drainage area relations. Some were a direct transfer based on ratio of drainage area from another station in the basin deemed hydrologically similar.

To determine the coincidental hydrographs on the Sheyenne, the analysis began at the downstream end at the confluence with the Red River. The balanced hydrographs on the Red River upstream of the Sheyenne were subtracted from the balanced hydrographs downstream of the Sheyenne to arrive at the corresponding coincident balanced hydrographs on the Sheyenne. This method hinges on the correct assumption of the Red River development of discharge-frequencies, upstream and downstream of the Sheyenne and the resulting development of balanced hydrographs at those locations. This method was deemed to be more preferable than beginning upstream of the Sheyenne River reach at the West Fargo, Mapleton, and Amenia gages, estimating coincidental peaks at those gages, developing discharge-frequencies, balanced hydrographs, estimating coincidental, incremental, local flow hydrographs and finally routing and combining along the reach to the confluence of the Red River.

Figure 65 to **Figure 80** show the flow volume frequency relationships for the direct analysis locations (main stem) and for the coincidental tributaries.

6.3 HYDROGRAPH DEVELOPMENT

Once these flow volumes for each frequency and duration were estimated, they were input to the HEC-1 computer program. **Figure 81** to **Figure 97** show the resulting balanced hydrographs with minor smoothing to maintain continuity. Because of limitations in methodology, balanced hydrographs on the Sheyenne River reach had to be smoothed to be representative of the pattern of the 2006 event and preserving flow duration volumes within the hydrographs. This was done in the unsteady modeling phase of the analysis. **Figure 98** shows the 2006 recorded event at the West Fargo gage for comparison.

7. OVERBANK STORAGE

Overbank Red and Wild Rice River storage south of Fargo and near the confluence of the Wild Rice River has attenuated the peak magnitude of past floods including the 2009 event. Following the 2009 flood, the St. Paul District initiated an unsteady RAS model specifically for this reach that more accurately routes flows. The Hydrologic Engineering

Center (HEC) was then tasked to further develop this model as a tool to evaluate synthetic event routing for the regulated condition – discharge frequency curve at Fargo. This analysis was needed for refining the discharge-frequency curve for the more extreme events. The model is presented in more detail in the Hydraulic Appendix.

8. SYNTHETIC EVENT DETERMINATION

Synthetic events were needed to define the upper portion of the regulated discharge-frequency curve at Fargo. This curve was developed graphically from 109 years of record and this is explained in **Appendix A-2**. The synthetic events that were developed were the 10-, 50-, 100-, 200-, and 500-yr. HEC then combined and plotted these events with their corresponding plotting position with the recorded events; adjusted 1902-1941 and unadjusted 1942-2009.

9. EXPERT OPINION ELICITATION

Recently, there has been an increasing amount of evidence indicating that the flow records at the Fargo gage can no longer be considered stationary. Data collected over the last century indicates that the frequency and magnitude of flooding has increased in the region. In addition, there have been suggestions that this increase in magnitude and frequency may be an artifact of possible climate change and portend or infer that this may be the condition of the future.

As previously described, the initial hydrologic analysis for the Fargo-Moorhead Feasibility Study was performed by applying the Log Pearson Type III distribution in accordance with Bulletin 17B and Corps guidelines. This methodology is only representative if a stationary flow record can be assumed. Furthermore, Bulleting 17B procedures assume climatic invariance. The observed increasing trends in flood flow frequency and magnitude calls this assumption into question. This raises the issue of whether or not the initially proposed curve accurately represents future conditions for the purposes of the feasibility study's risk analysis.

To address these issues, the Corps project delivery team (PDT) organized an expert opinion elicitation (EOE). The EOE was established to provide the PDT with specific actions that should be taken, if any, to account for the suspected non-stationarity and uncertainty associated with the flow recorded in the Fargo-Moorhead metropolitan area and assess possible future climatic change impacts. The Fargo-Moorhead EOE was held on September 28-29, 2009, in Bloomington, MN. Participants in the EOE included six experts chosen by the St. Paul District, five invited observers, and USACE- St. Paul District staff. David Ford, PhD, PE, D. WRE, served as technical integrator and facilitator. Experts and panel members were provided with a read-ahead guide on the subject of non-stationarity in flow records, project assumptions, a summary outlining the EOE process and an overview of the Fargo-Moorhead feasibility study.

After these introductory materials were reviewed by those in attendance, the subsequent four questions were poised:

1. Is it likely that climate change will have a significant impact on the flood flow frequency curve during the life of the proposed flood risk reduction project for Fargo, ND- Moorhead, MN?

2. How will the frequency curve change?

3. What are the practicable alternatives for accounting for the impact of change?

4. Of the alternatives available, which is best for this particular application, given the limitations imposed by the urgent need to reduce risk in Fargo-Moorhead?

Following extensive discussion between observers, Corps representatives and experts, the expert panel members wrote up their final opinions on the issues presented before the panel. The panel members concluded that there was not enough information regarding future climate change to incorporate that effect in the discharge-frequency analysis. However, the members did declare the current flow record at Fargo from 1900 to the present, as non-stationary. Discussions then focused on ways this issue could be addressed. Taken together, points made during group discussions and the experts' written responses suggested that the following steps should be taken to adjust the flood frequency curve used in the hydrologic analysis supporting the Fargo-Moorhead feasibility study:

1. Develop, and use as the basis for the frequency analysis, an unregulated time series. Prior to the addition of significant regulation in the system, the series will be the recorded flows. After regulation was added, the recorded flows must be adjusted to "remove" the effects of regulation in the system. This can be done with the reservoir and channel routing models that the District has available.
2. Develop and use a transform function to convert the derived unregulated frequency function to the regulated frequency function that is required for the risk analysis. This transform function can be developed by simulating system behavior without and with regulation for floods from the period of record (POR). As the historical floods may fail to cover adequately the range of flows needed to define the frequency curve well, historical events can be scaled to simulate larger floods. This is consistent with guidance in EM 1110-2-1415.
3. Analyze the unregulated flow series, and divide the current POR into two portions. Suggestions for identifying the "break" between the wet period and the dry period included:
   - Using qualitative judgment, e.g., define the dry period as 1901-1941 and the wet period as 1942-2009; or define the dry period as 1901-1960 and the wet period as 1961-2009.

- Use statistical tests for homogeneity to determine where to divide the POR. The expert panel did not agree on the statistical tests, but did not work by Villarini, et al.

4. Fit a log Pearson III distribution separately to the dry components of the split record and the wet component, following generally the guidance in *Bulletin 17B*. Some members of the panel suggested using the total record to estimate the skew coefficient to be used for both components. Others suggested determining the skew coefficients for each portion of the POR separately. If the skew coefficients are close, an appropriately rounded average of the two could be used.
5. Combine the "wet" and "dry" curves, and weight the probabilities for continued wet conditions versus a reemergence of dry conditions. Two schemes emerged from the majority of the experts' responses:
   - Transition from wet to dry over time. For example, begin with probability of wet [p(wet)=1] and probability of dry [p(dry)=0] in year 1 of the project, moving to p(wet)=0.5 and p(dry)=0.5 in year 50, or move p(wet) from 1 to 0 over the life of the project.
   - Do not change the probabilities over time. One proposed set of values was p(wet)=0.8 and p(dry)=0.2 over the entire 50-year project life. It was recognized that there is a good deal of subjectivity in the selection of these values, but experts felt it would be prudent to set a substantially higher probability on the wet condition than the dry one. Under this recommendation, setting p(dry) to zero was felt to be inappropriate, as a return to the dry condition is certainly possible.
6. Account for greater uncertainty. One suggestion was to use an equivalent POR in the Corps Hydrologic Engineering Center's Flood Damage Analysis (HEC-FDA) equal to the number of years of the smaller portion of the POR (either the wet portion or the dry portion).

Corps members from the St. Paul district reviewed each of these suggestions and carried out preliminary analysis in order to develop a plan for incorporating these recommendations into the Fargo-Moorhead Feasibility study. Part of this strategy included drafting a contract between the St. Paul District and the Corps Hydrologic Engineering Center (HEC) to implement the recommendations of the EOE. This involved developing a methodology that can be applied to produce weighted Flow Frequency Curves (as described by the EOE). Using the tools developed by HEC, the Corps in-house PDT will be able to assess by sensitivity analysis the initial flow-frequency analysis, taking the foreseeable effects of non-stationarity into consideration and further evaluate impacts based on the aforementioned assumptions. This will ensure that the Corps produces a reliable and robust plan and design for the proposed Fargo-Moorhead flood protection project.

The EOE final report is appendix A-1b.

Table 31 - Flood Volume Type and Method of Development

	Station	River	Volume Type	METHOD Relative ratios volume frequency; direct analysis of:
Gauged				
	Halstad	Red River	main stem	Halstad
	Fargo	Red River	main stem	Fargo
	Hickson	Red River	main stem	Hickson
	Wahpeton	Red River	main stem	Wahpeton
	West Fargo (old channel)	Sheyenne	Coincidental	West Fargo
	Hendrum	Wild Rice River, MN	Coincidental	Hendrum
	Dilworth	Buffalo River	Coincidental	Dilworth
	Abercrombie	Wild Rice River, ND	Coincidental	Abercrombie
Ungauged				
	Red ds Wild Rice, MN	Red River	main stem	Halstad
	Red River ds Buffalo River	Red River	main stem	Halstad
	Red River ds of Sheyenne River	Red River	main stem	Halstad
	Red River us of Sheyenne River	Red River	main stem	Fargo
	Wild Rice River, MN us of confluence	Wild Rice River, MN	coincidental	Same as Hendrum coincidental
	Buffalo River us of confluence	Buffalo River	coincidental	Dilworth: Ratio coincident peaks to confluence by general relations; Sabin & Dilworth
	Wild Rice River, ND us of confluence	Wild Rice River, ND	coincidental	Abercrombie coincidental: transfer to confluence by general relations; Abercrombie & Rutland
	Sheyenne River us of confluence	Sheyenne River	coincidental	Subtraction: Red ds of Sheyenne from Red us of Sheyenne
	Sheyenne River ds of Rush River	Sheyenne River	coincidental	Direct translation from Sheyenne R us of Red coincidental
	Rush River at confluence	Rush River	coincidental	Dilworth: Ratio coincident peaks to Buffalo coincident peaks @ confluence: 0.145
	Sheyenne River us of Rush	Sheyenne River	coincidental	Rush R at confluence coincidental + Sheyenne ds of Rush coincidental
	Sheyenne River ds of Maple River	Sheyenne River	coincidental	West Fargo: Ratio coincident peaks to Sheyenne us of Red: 0.951
	Maple River us of confluence	Maple River	coincidental	Dilworth: Ratio coincident peaks to Buffalo coincident peaks @ confluence: 1.276

10. REFERENCES

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2. HEC-FFA "Flood Frequency Analysis", U.S. Army, Corps of Engineers, Hydrologic Engineering Center, May 1992.

3. "HEC-5, Simulation of Flood Control and Conservation Systems", Hydrologic Engineering Center, Corps of Engineers, October 1998.

4. "Hydrologic Analyses for Flood Insurance Studies, The Red River of the North Main Stem, from Wahpeton/Breckenridge to Emerson, Manitoba", St. Paul District Corps of Engineers, May 2000.

5. "Revision to the September 2000 section 205, Flood Reduction Feasibility Studies for Breckenridge, Minnesota, Appendix A, Hydrologic Analysis", St. Paul District, Corps of Engineers, September 2001.

6. HEC-RAS "River Analysis System", U.S. Army, Corps of Engineers, Hydrologic Engineering Center, Version 2.2, September 1998.

7. "HEC-1, Flood Hydrograph Package", U.S. Army Corps of Engineers, Hydrologic Engineering Center, June 1998.

8. Volume I, Timing Analysis" for the Technical Resource Service, Red River of the North", Department of Defense, St. Paul District U.S. Army Corps of Engineers, March 1988.

FIGURES

Figure 1- Red River of the North Basin and Mainstem Stream gages

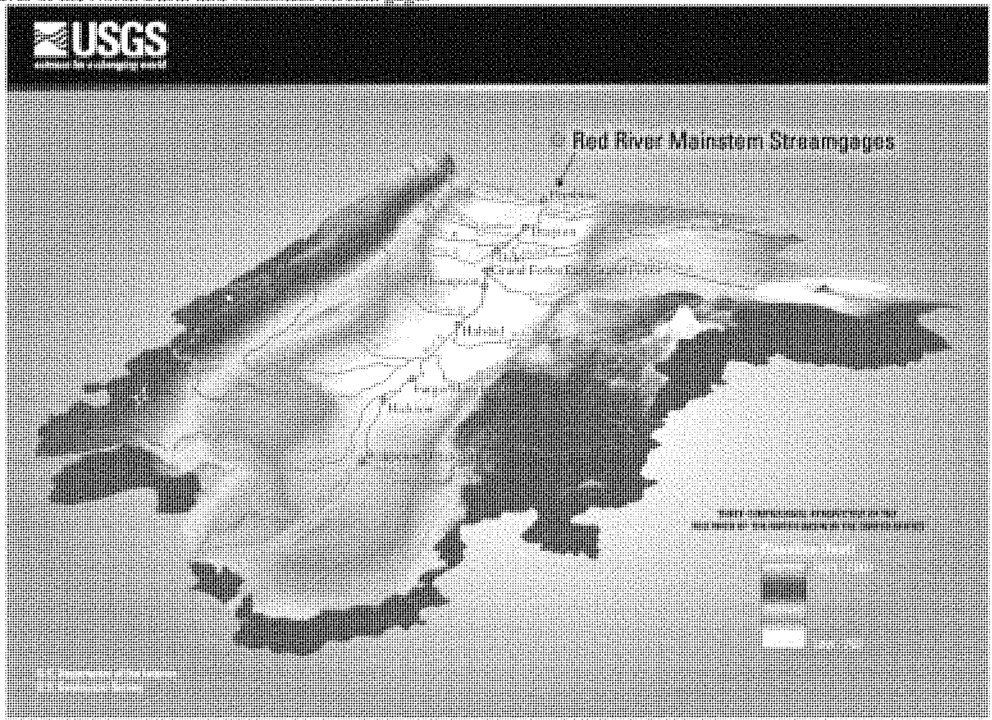


Figure 2-Red River of the North: Sheyenne & Upper Red Basin above Fargo

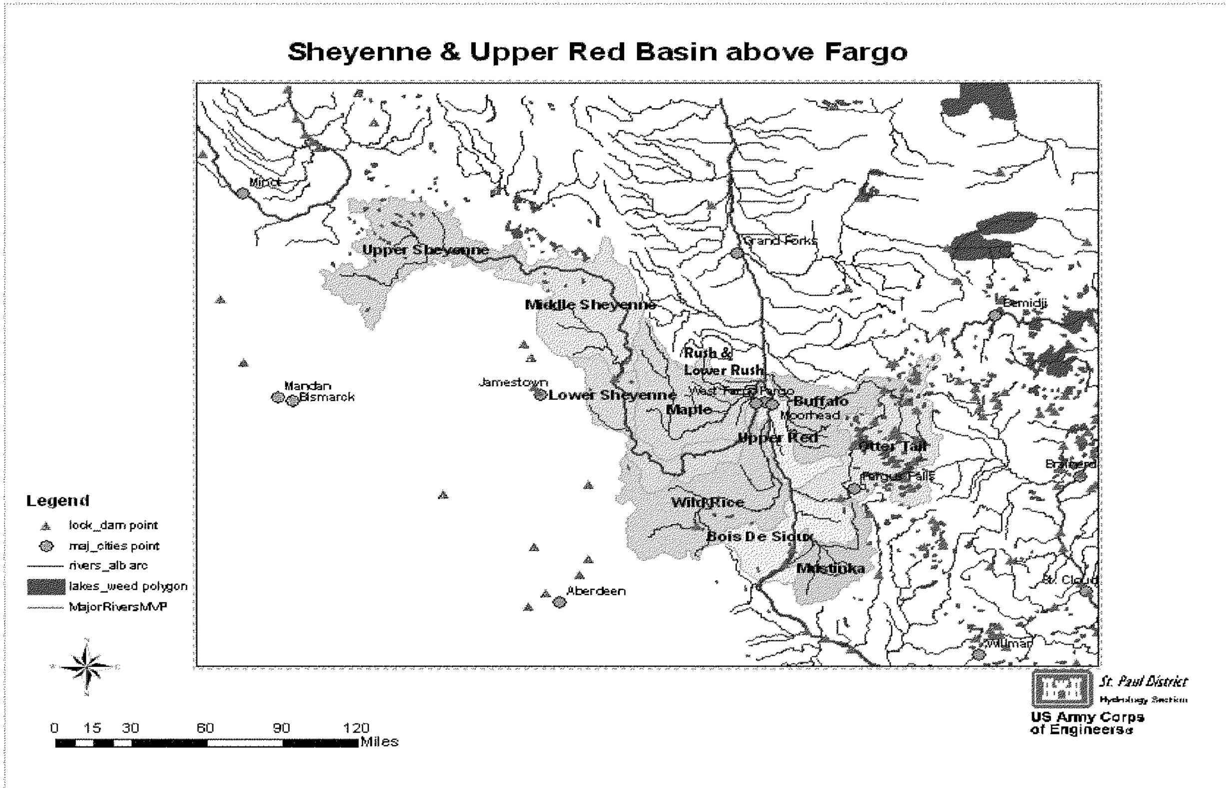


Figure 3- Model Schematic

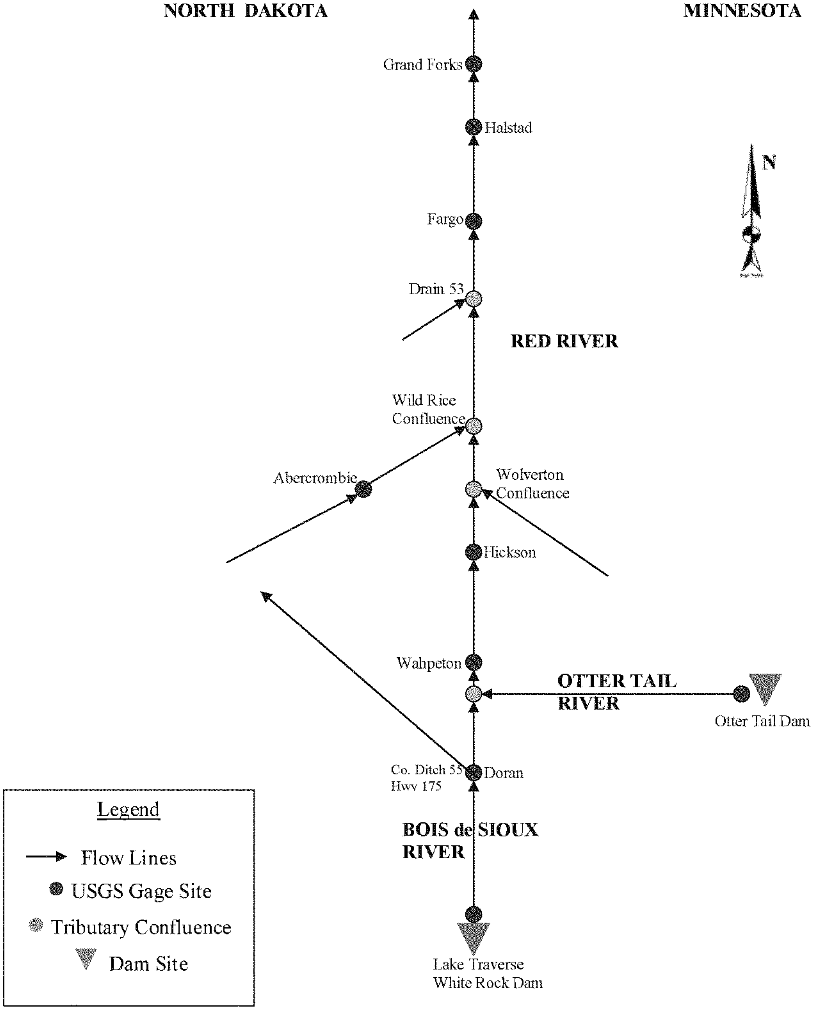


Figure 4- Model Schematic

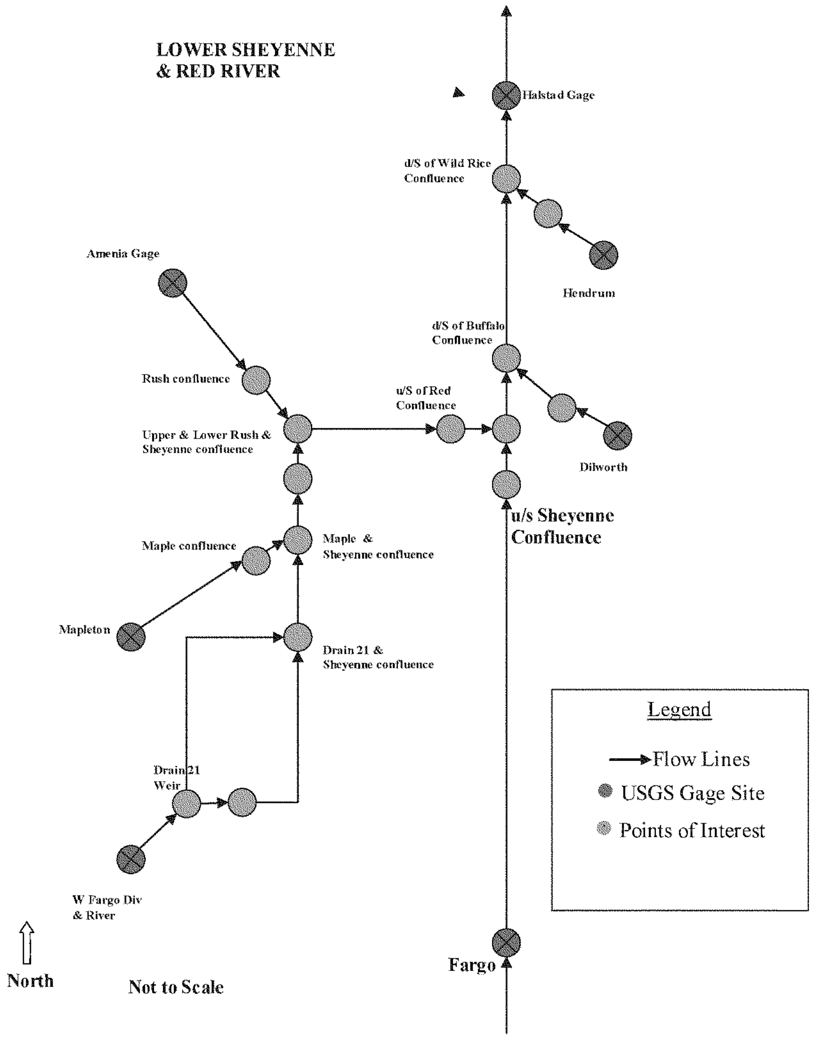


Figure 5- Drainage Area Schematic for Hec-5

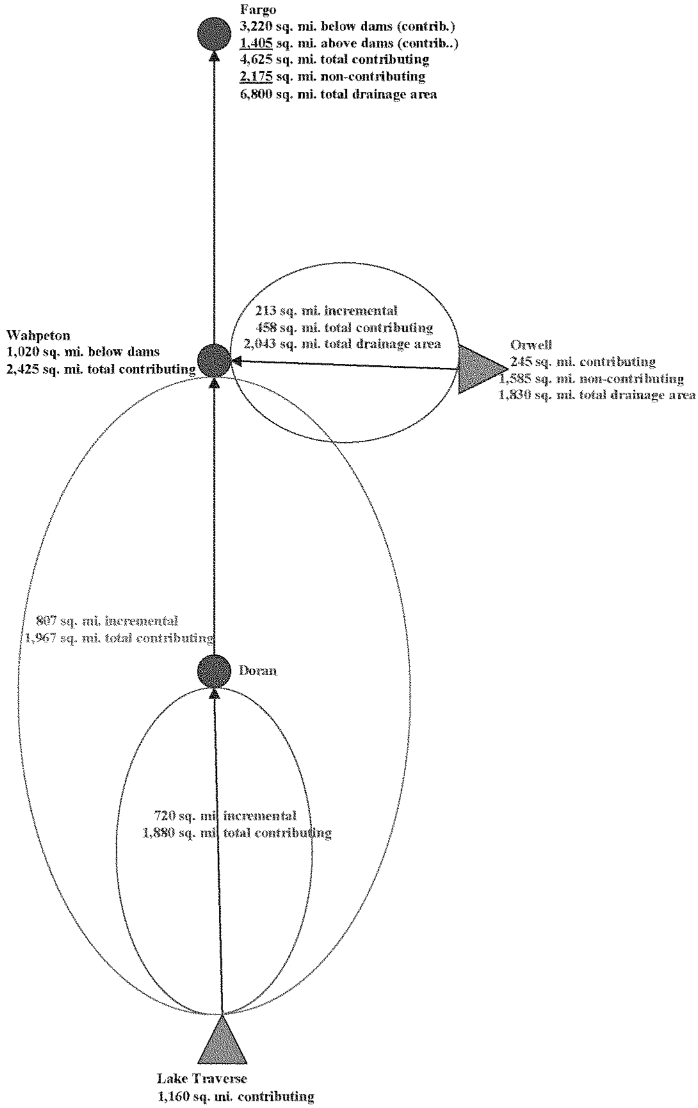


Figure 6- Bois de Sioux River Breakout Flow Schematic

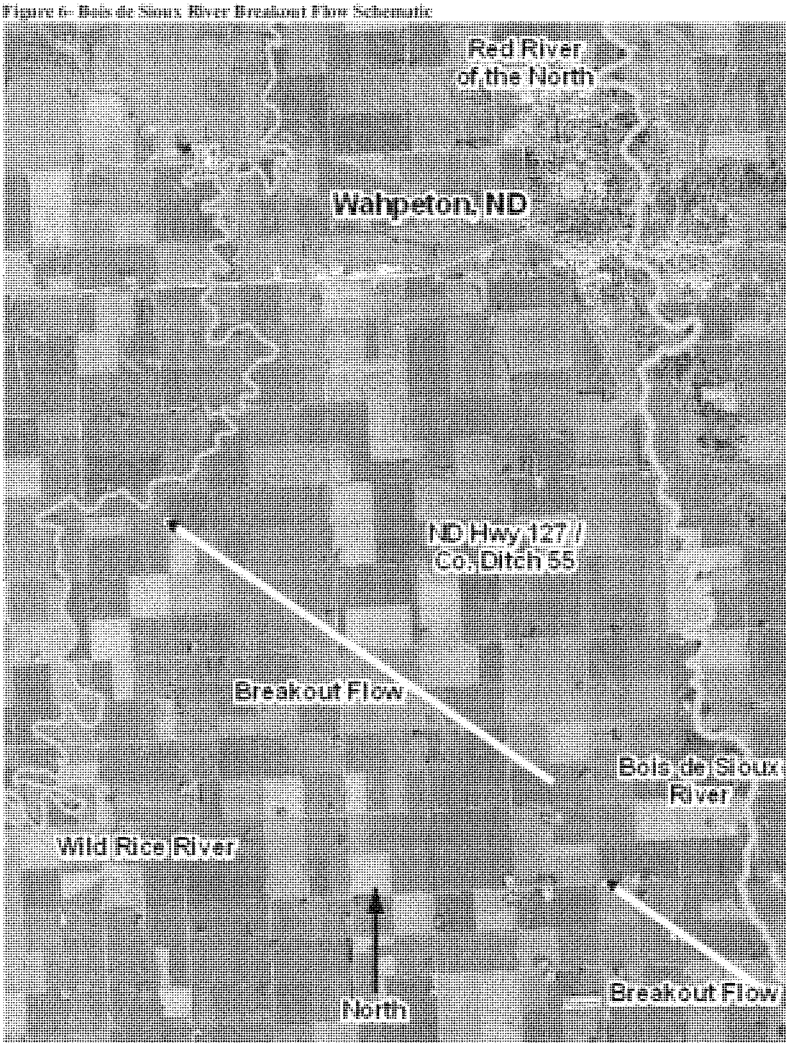


Figure 7- Major Drainage Area Subdivided at Pertinent Locations for the Sheyenne River

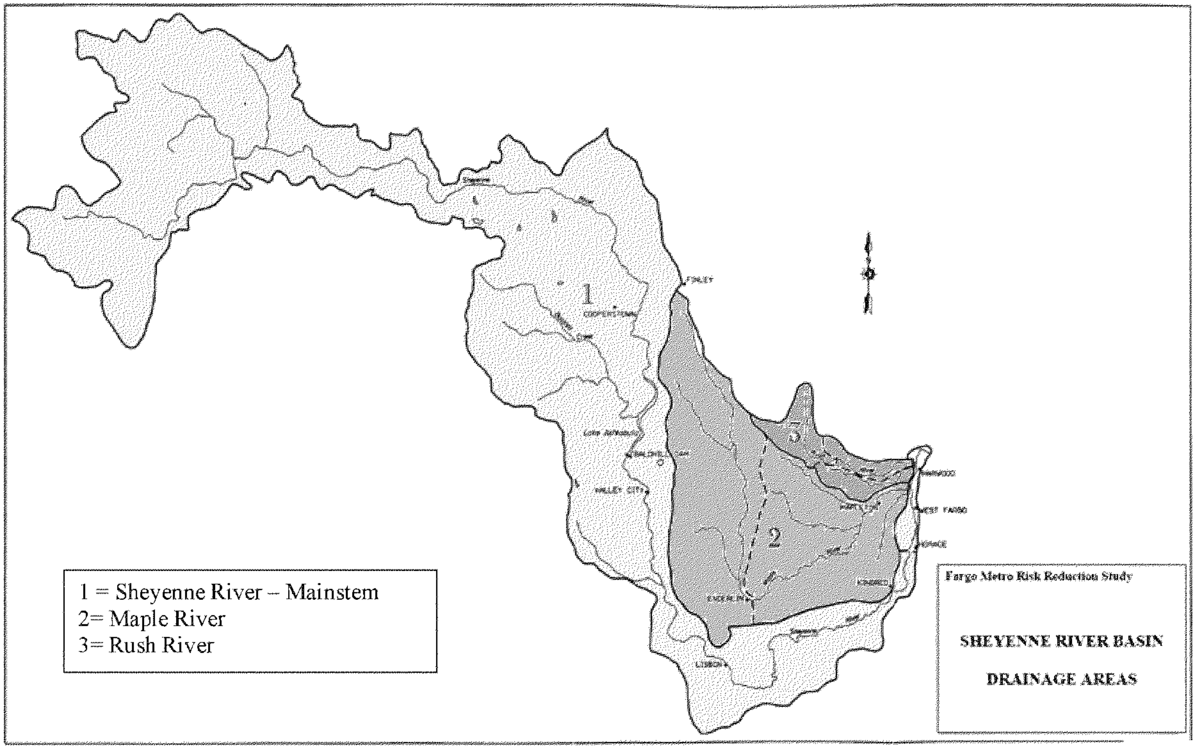
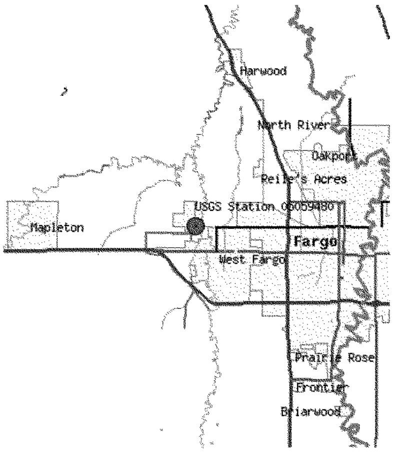


Figure 8- USGS Gage locations



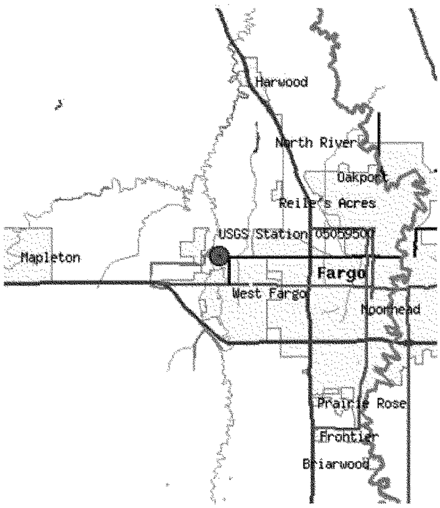


Figure 9- Peak Streamflow Gage Stations and Period of Record

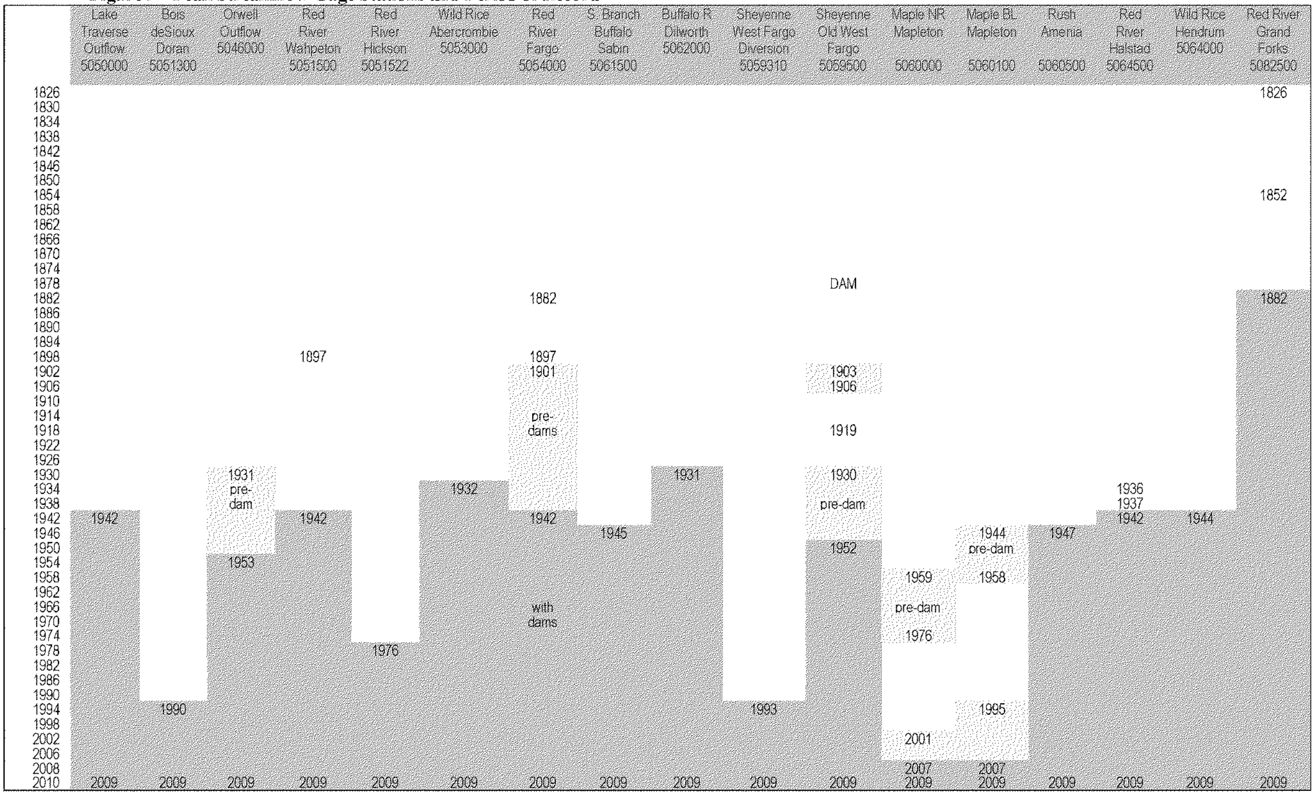


Figure 10- Lake Traverse Project Map

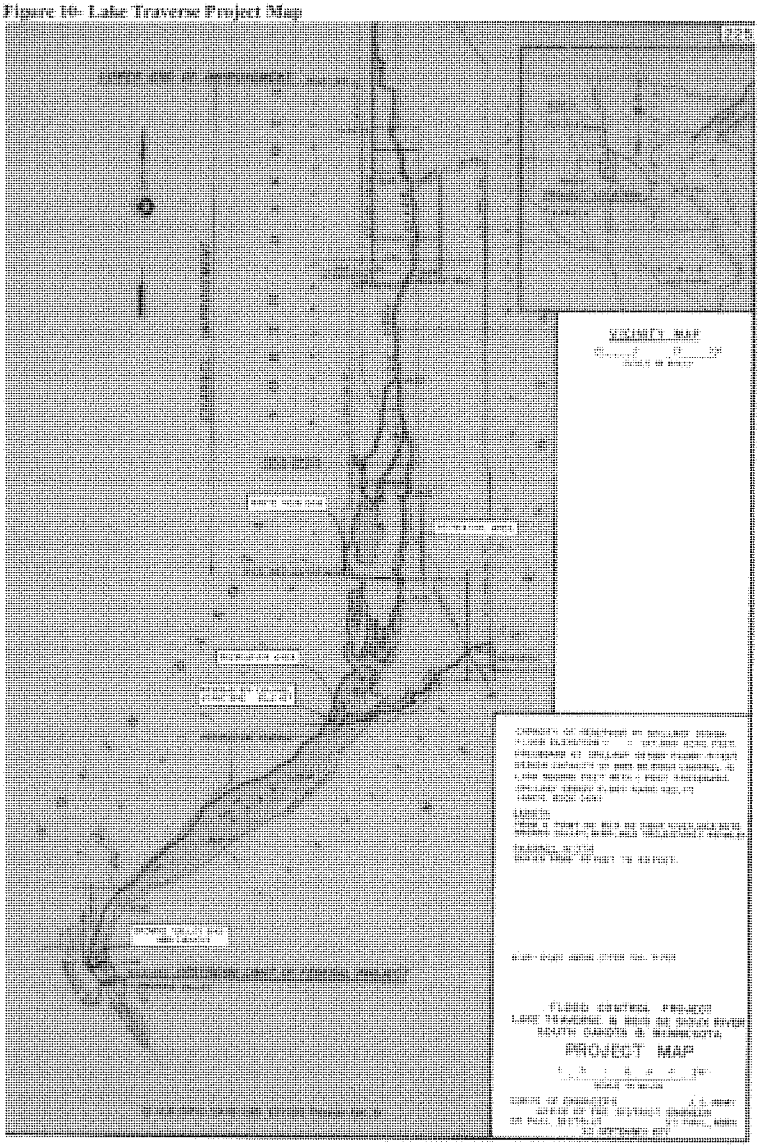


Figure 11- White Rock Dam, Lake Traverse Project (Looking Downstream)

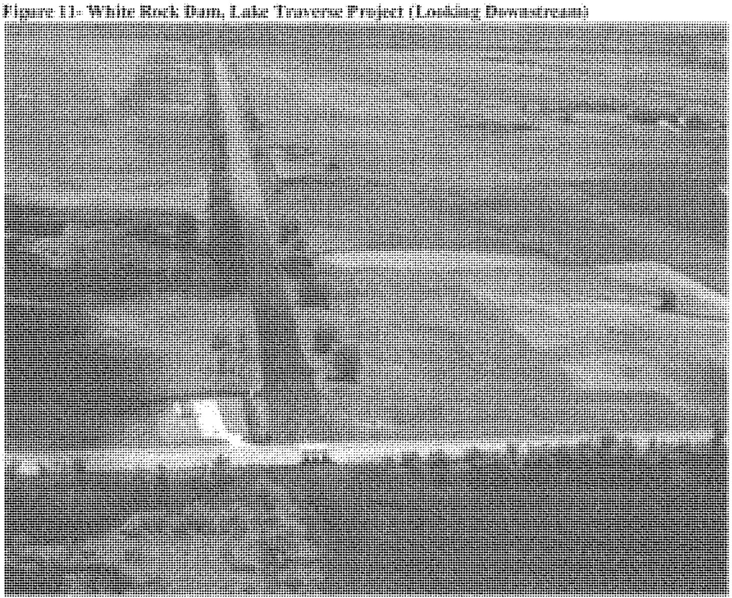


Figure 12- Orwell Reservoir Project Map

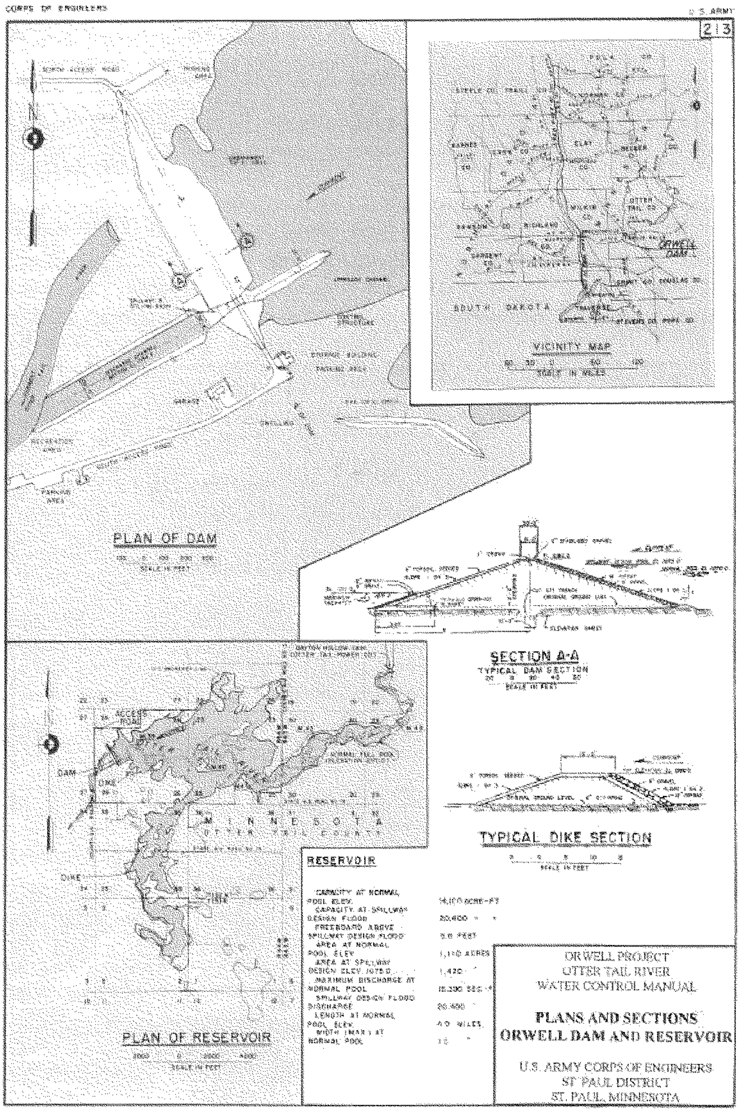
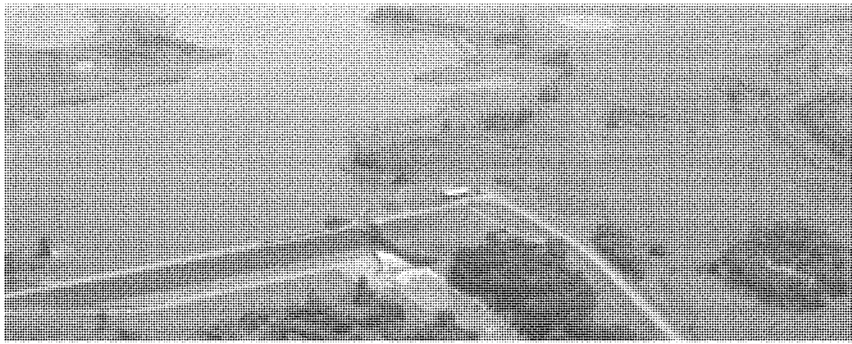


Figure 13- Orwell Dam photographs



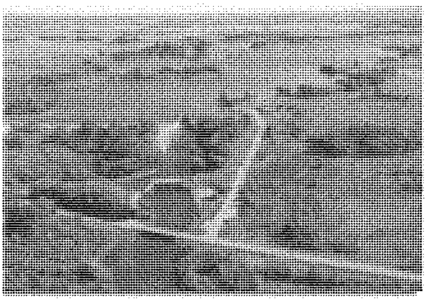


Figure 14- Project Map for Baldhill Dam

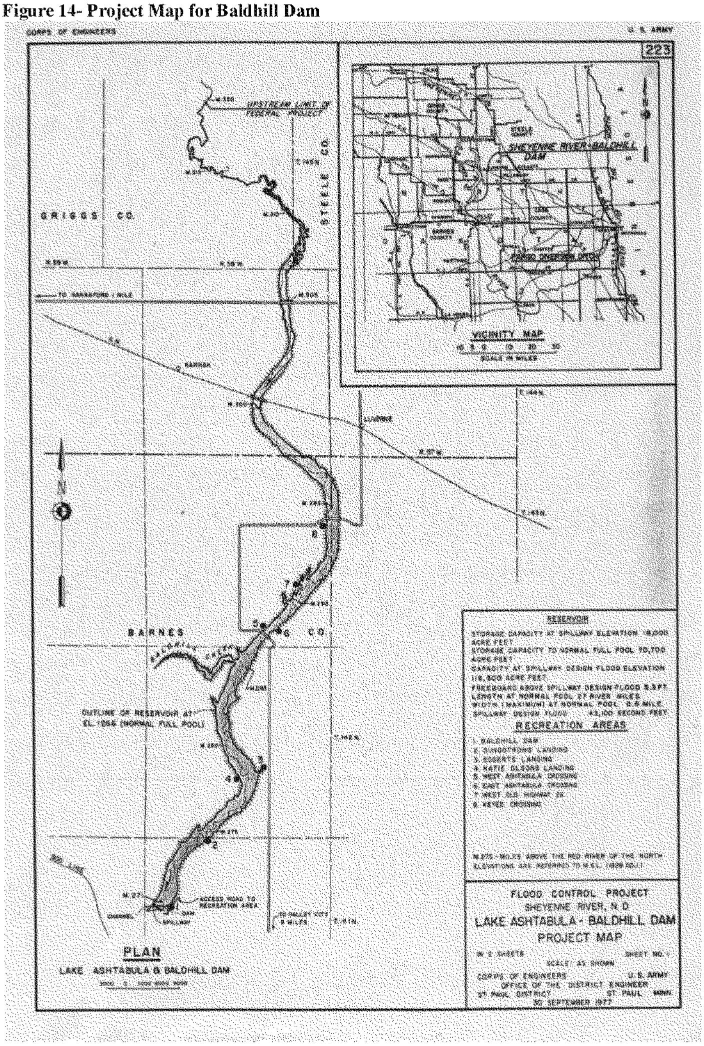


Figure 15- Baldhill Dam Photograph

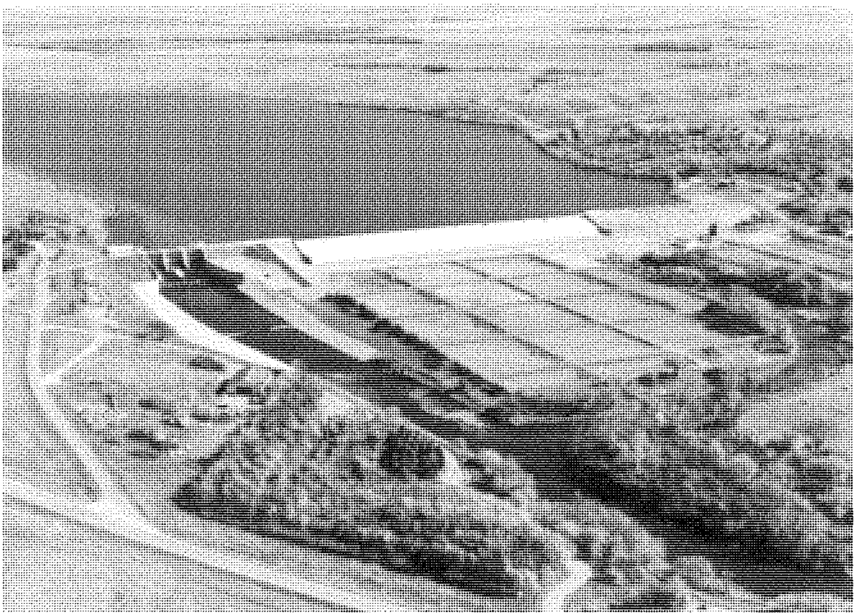


Figure 16. Red Lake Project Map

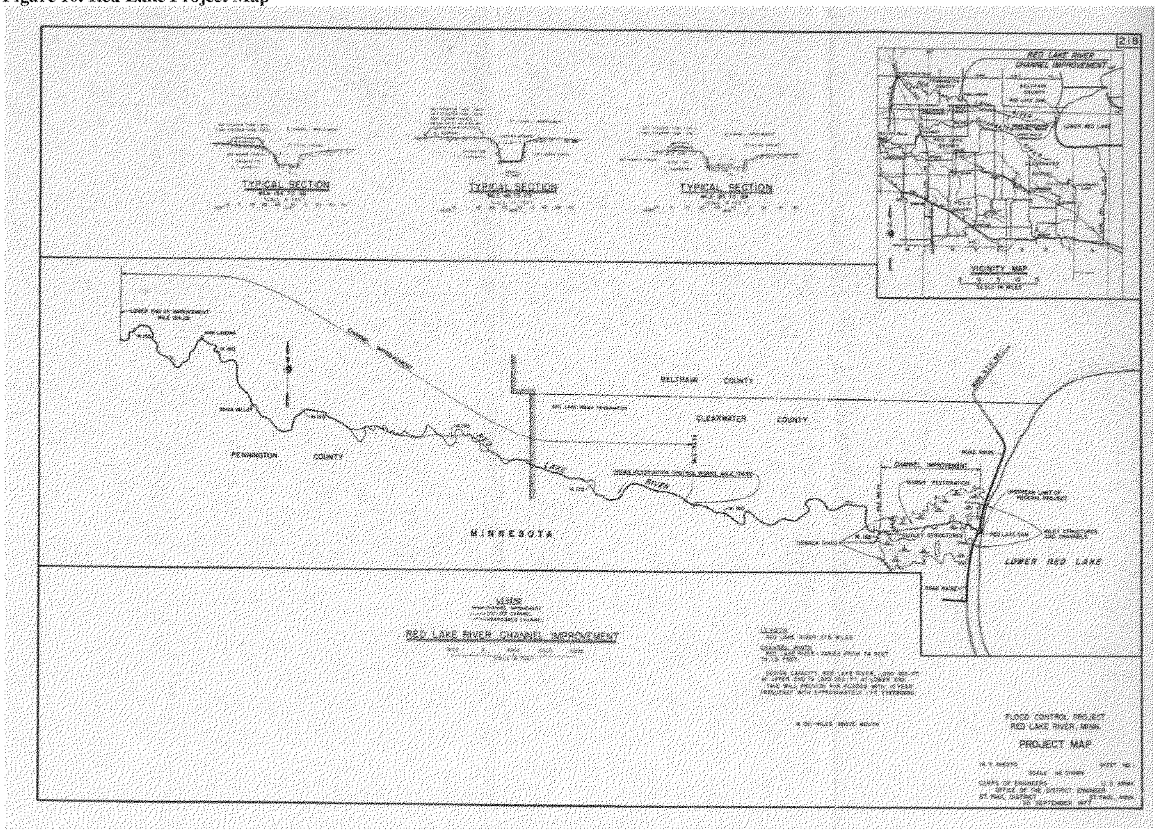


Figure 17. Red Lake Dam photograph

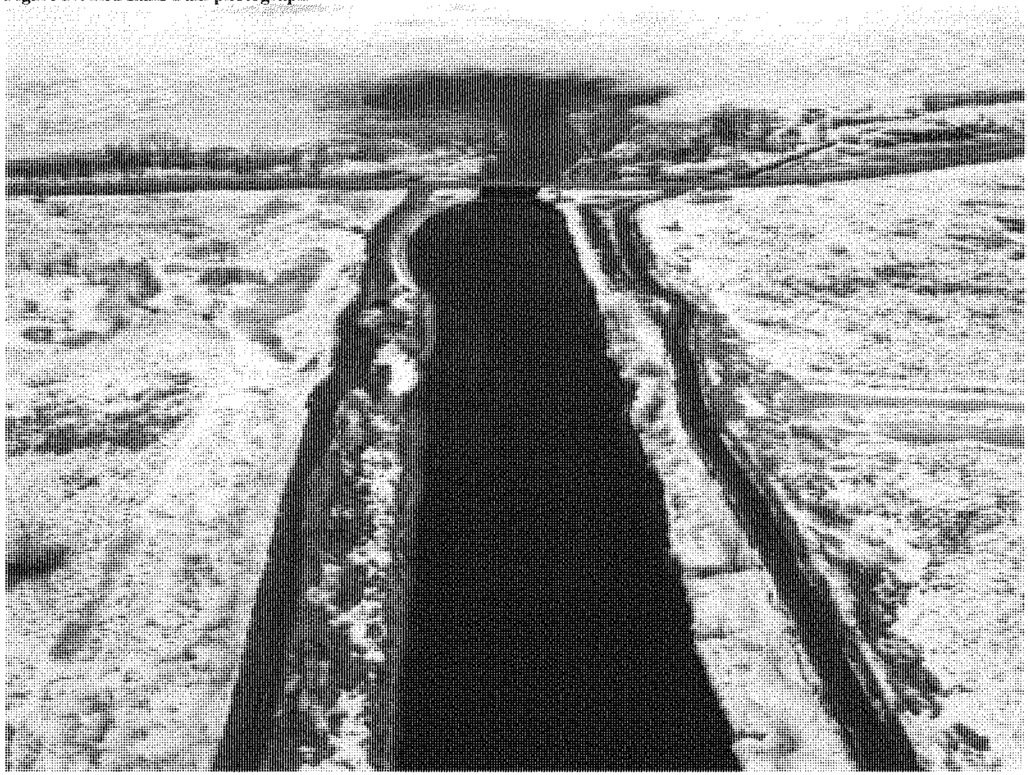


Figure 18- Hydrographs for Spring 1997 Event for Lake Traverse

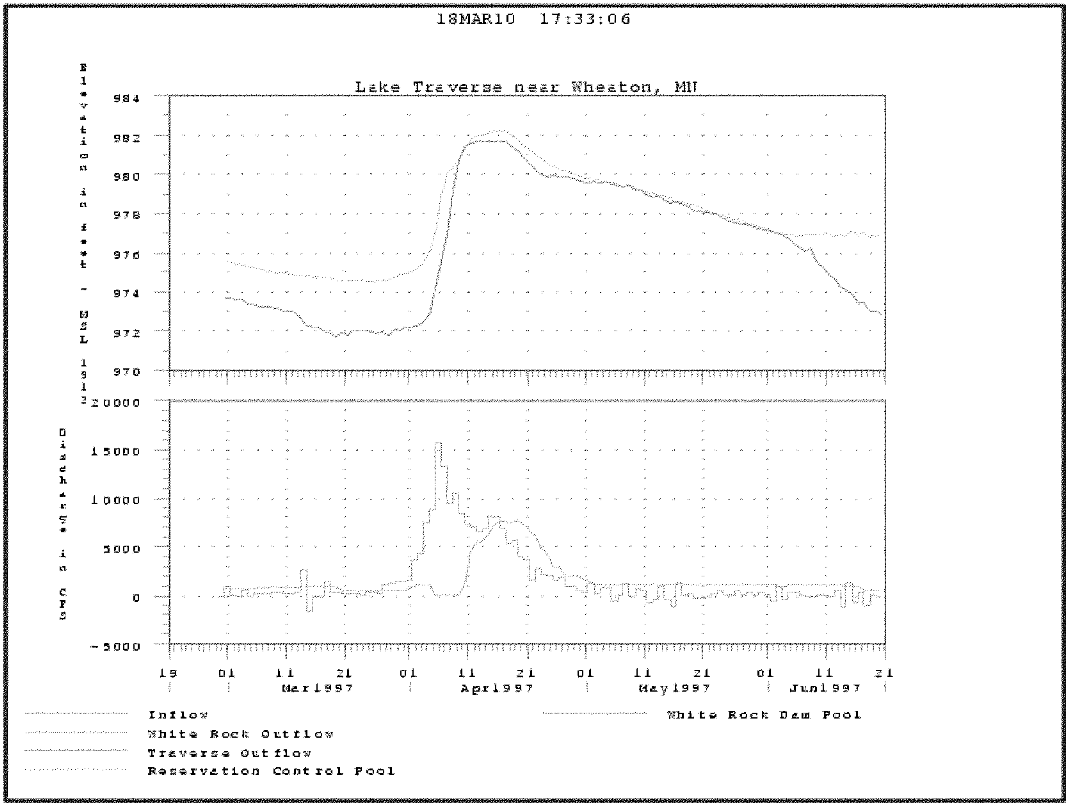


Figure 19- Hydrographs for Spring 1997 Event Orwell Dam

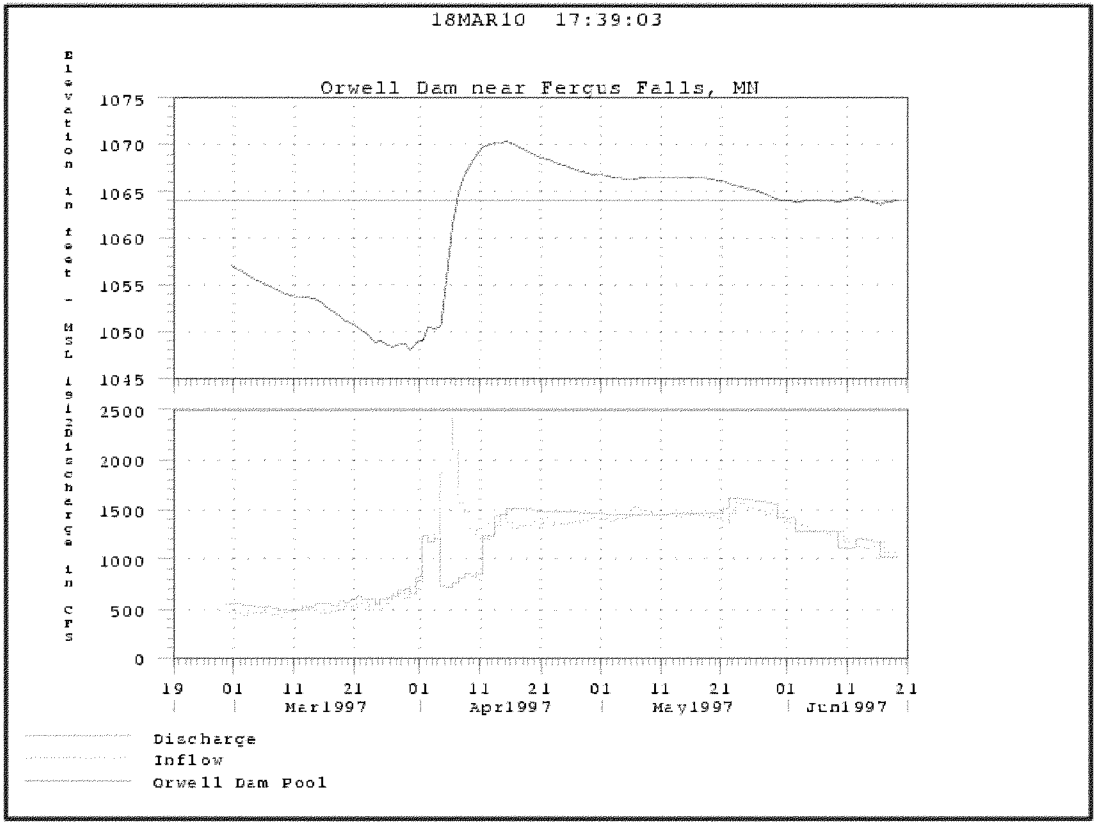


Figure 20- Hydrographs for Spring 1997 Event for Baldhill Dam

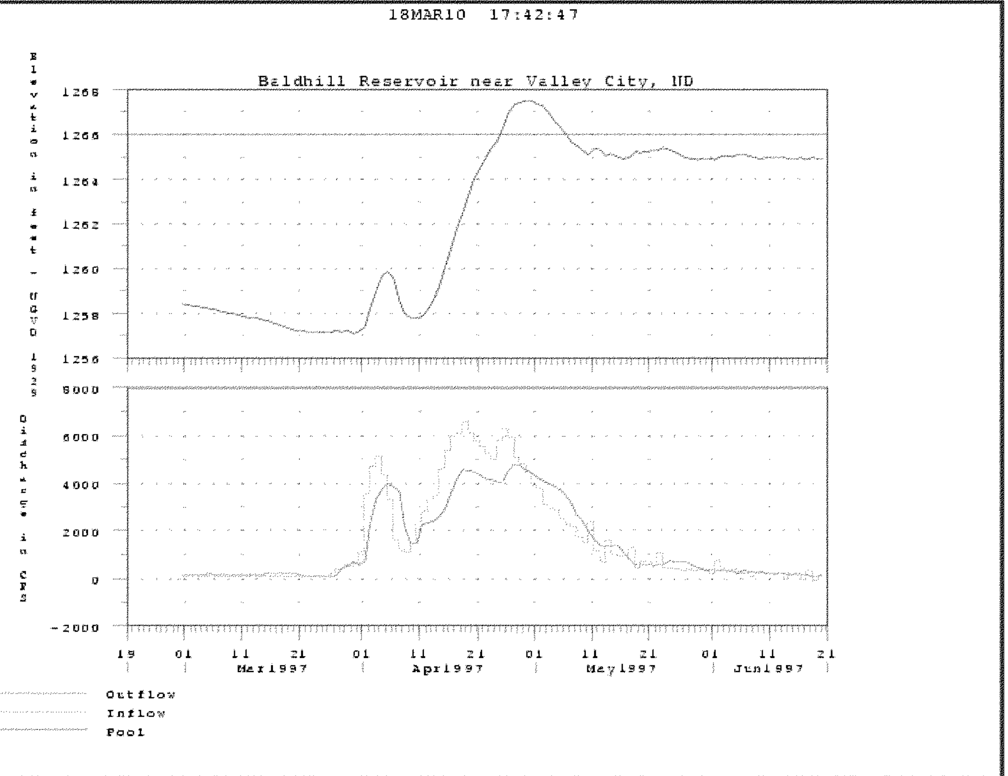


Figure 21. Spring 1997 Event at Red Lake Dam

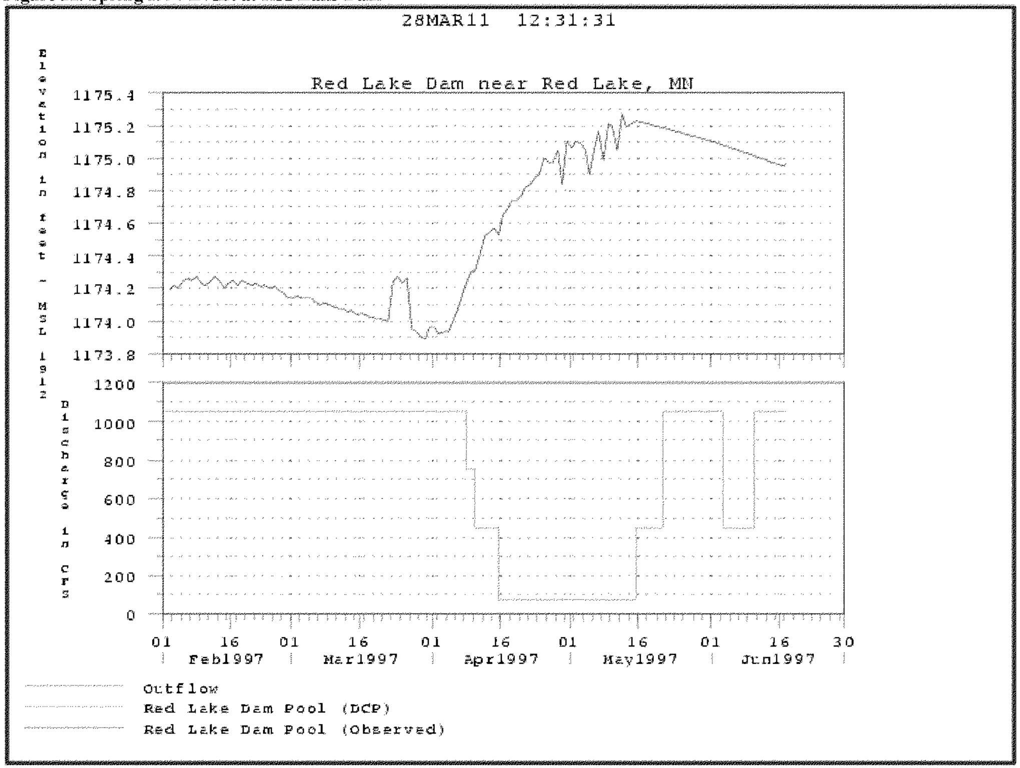


Figure 22- Hydrograph for Spring/Summer 2001 Event Lake Traverse

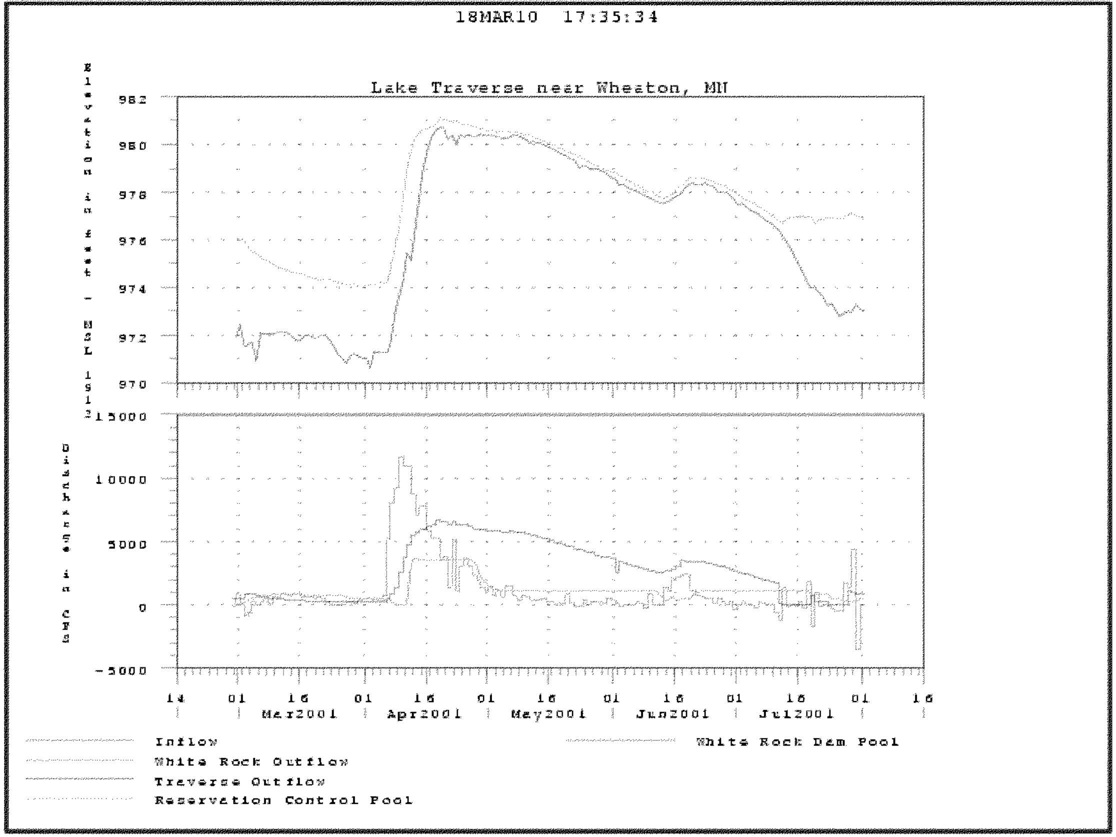


Figure 23- Hydrograph for Spring/Summer 2001 Event Orwell Dam

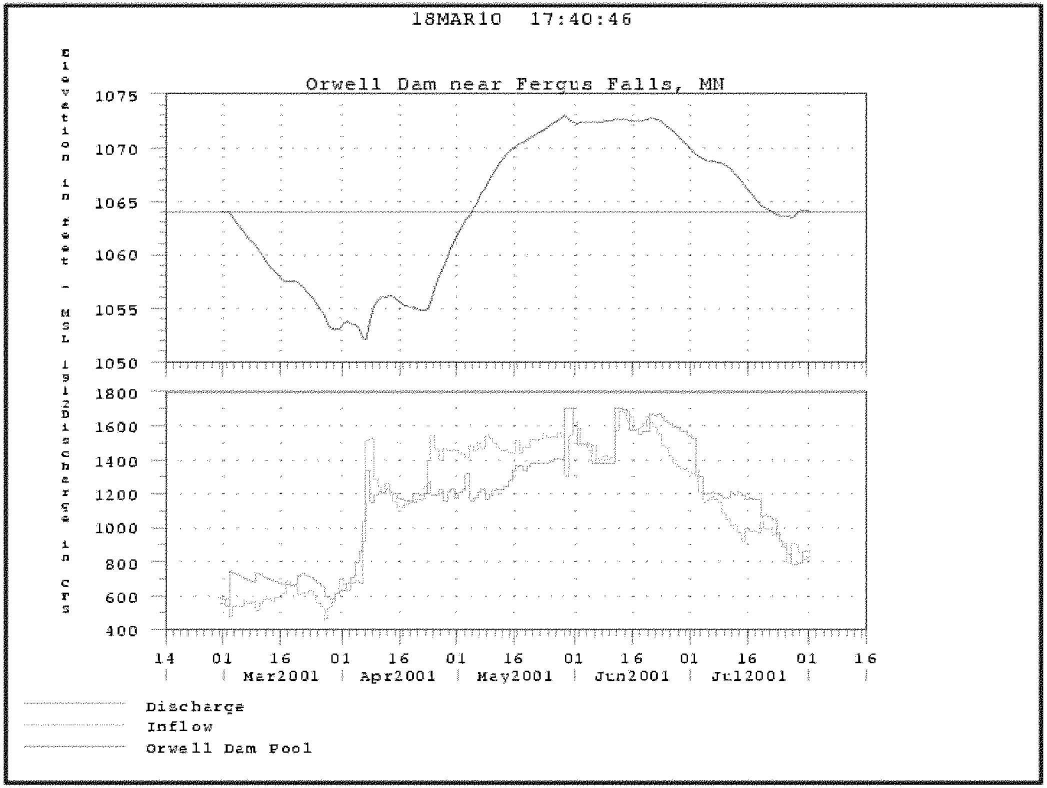


Figure 24- Hydrograph for Spring/ Summer 2001 Event for Baldhill Dam

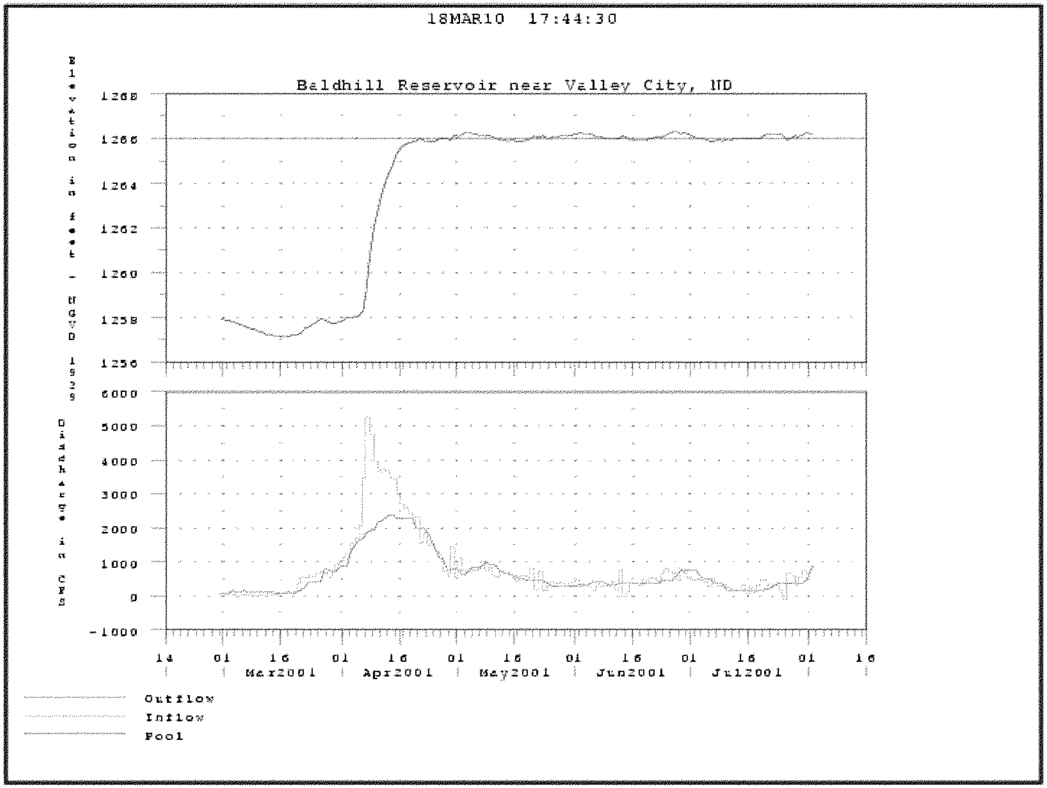


Figure 25. 2001 Spring Event at Red Lake Dam

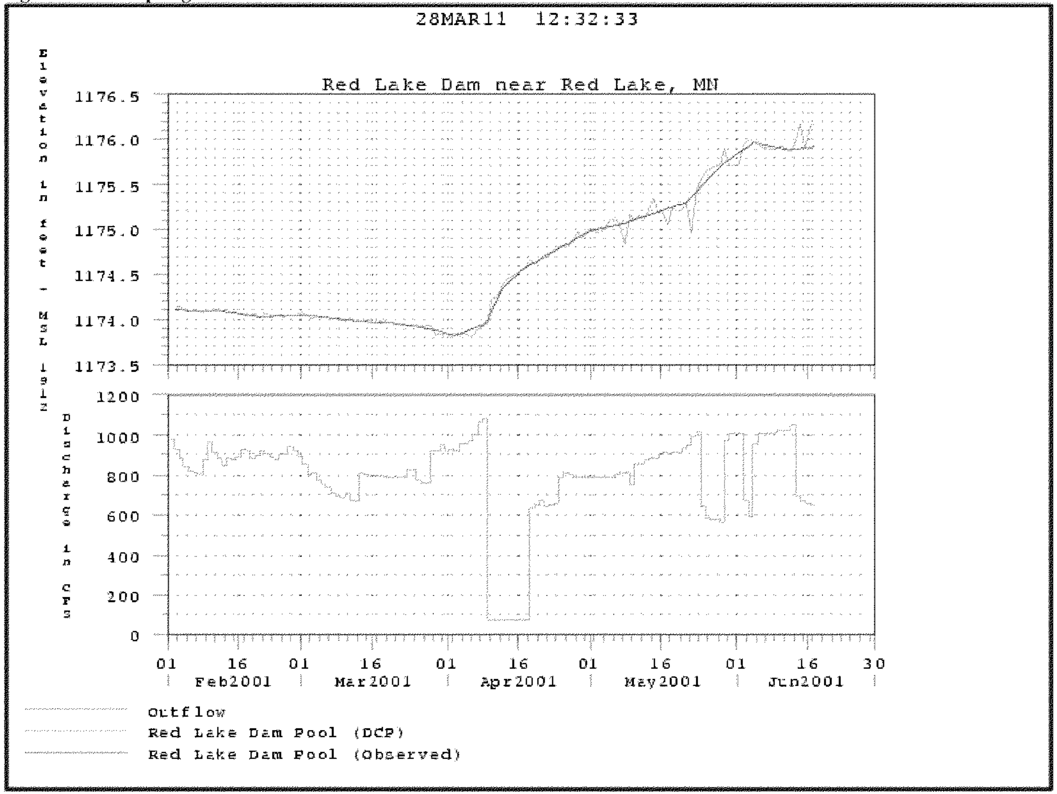


Figure 26. Hydrograph for Spring 2006 Event Lake Traverse

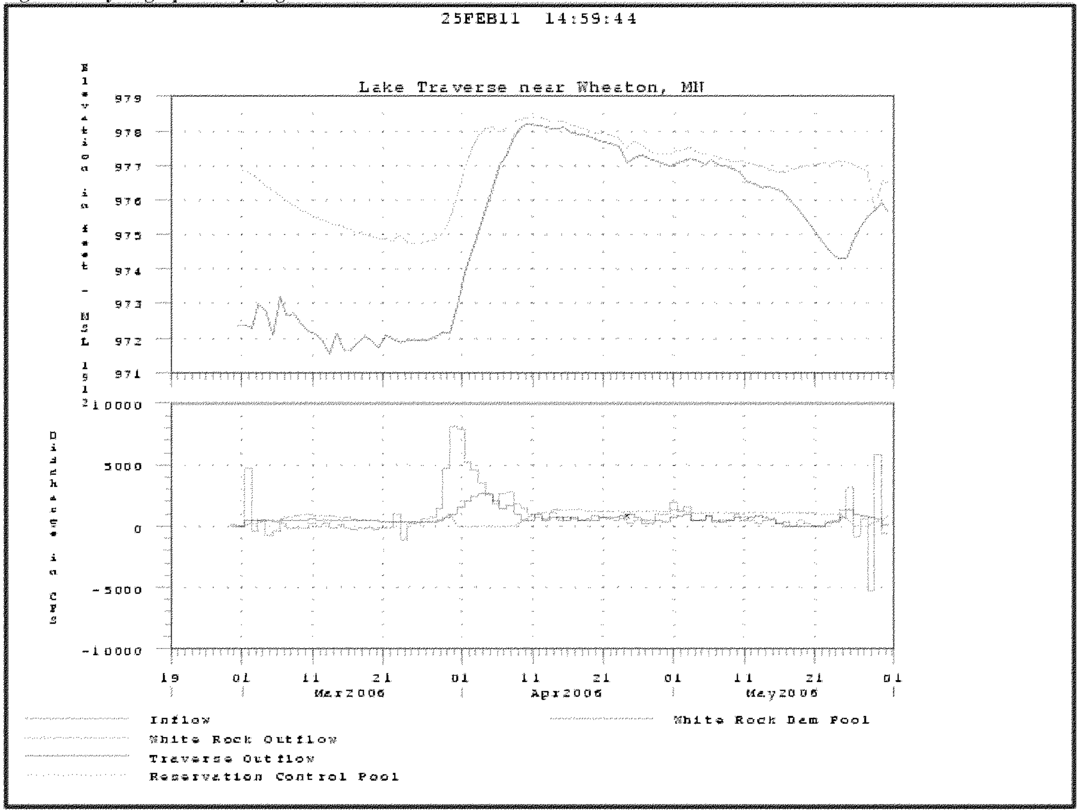


Figure 27. Hydrograph for Spring 2006 Event Orwell Dam

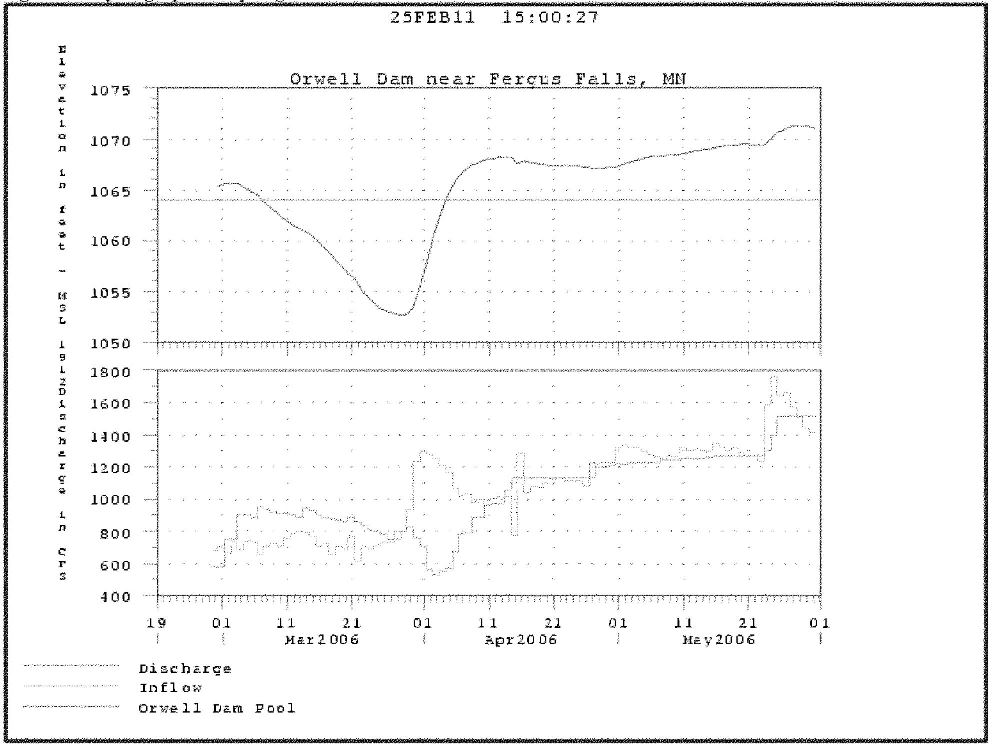


Figure 28. Hydrograph for Spring 2006 Event Baldhill Dam

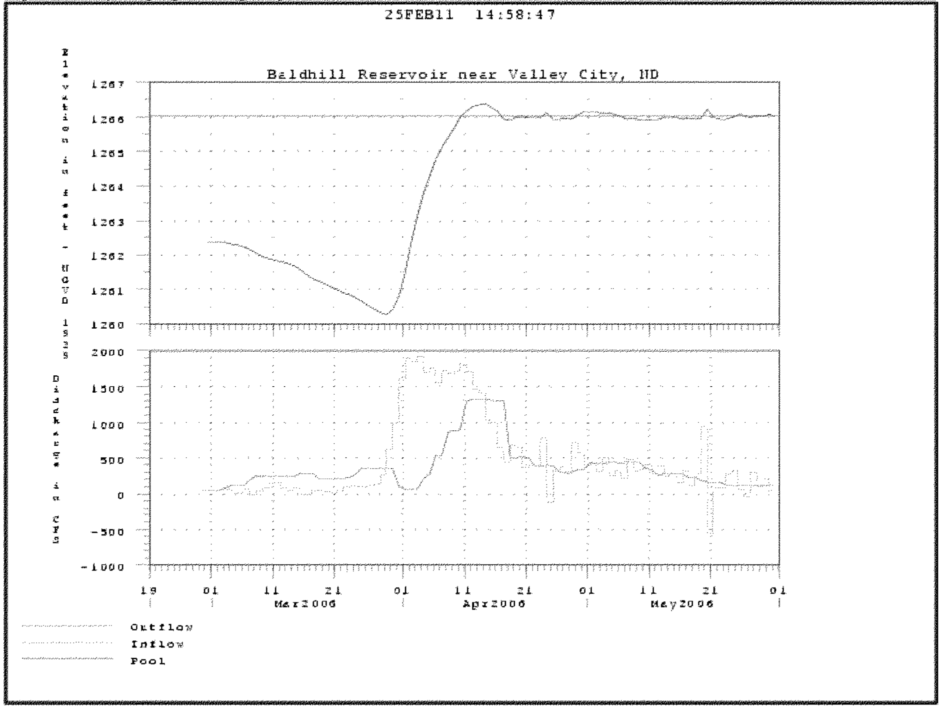


Figure 29- Hydrograph for Spring Flood Event 2009 Lake Traverse

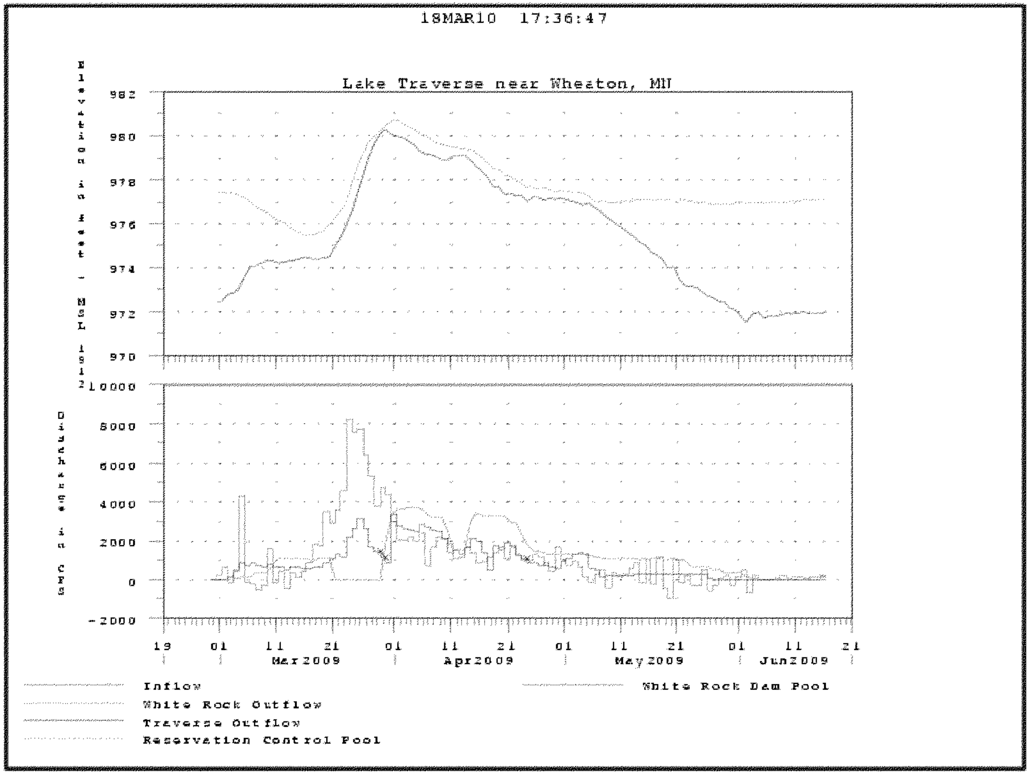


Figure 30- Hydrograph for Spring Flood Event 2009 Orwell Dam

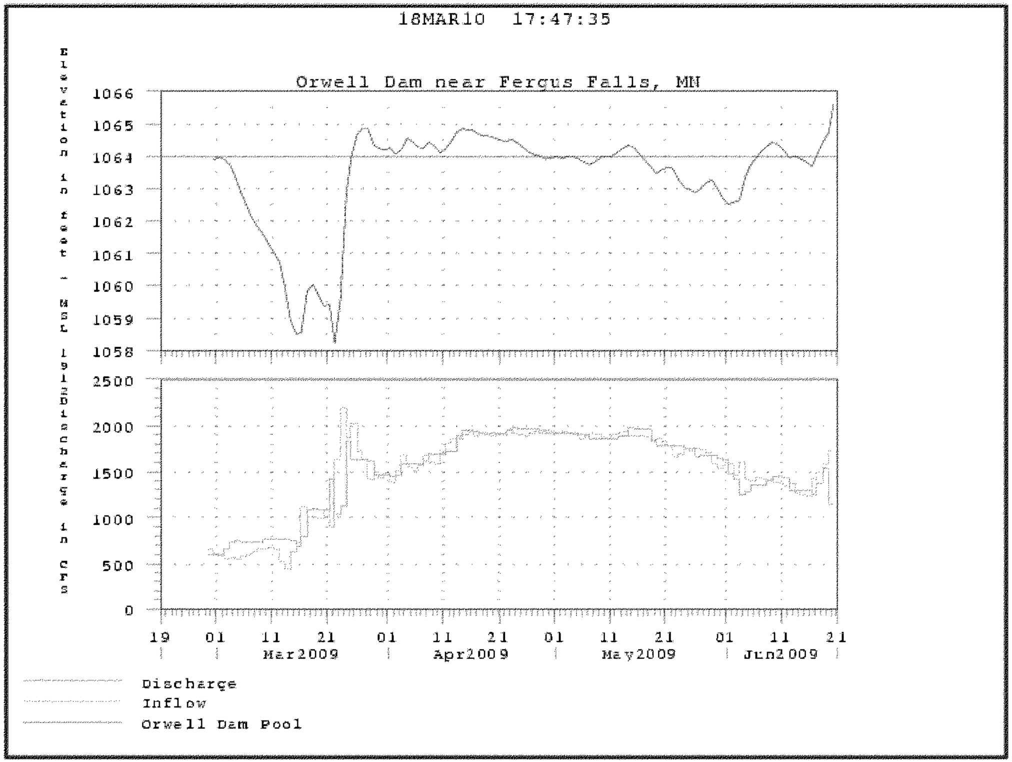


Figure 31- Hydrograph for Spring Flood Event 2009 Baldhill Dam

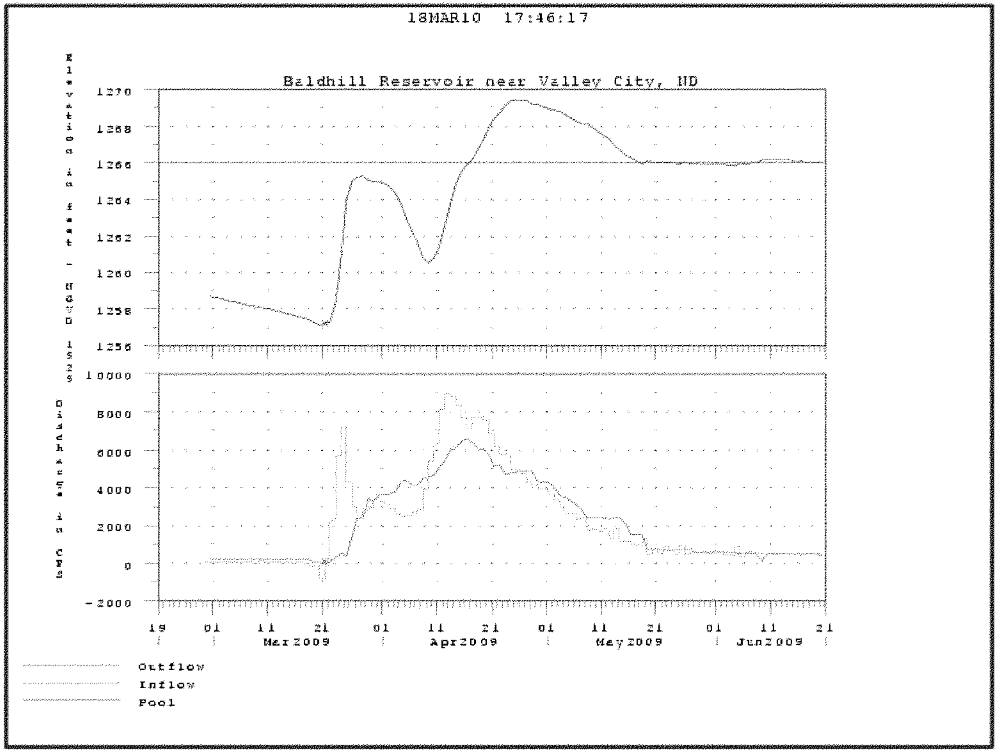


Figure 32. 2009 Event at Red Lake Dam

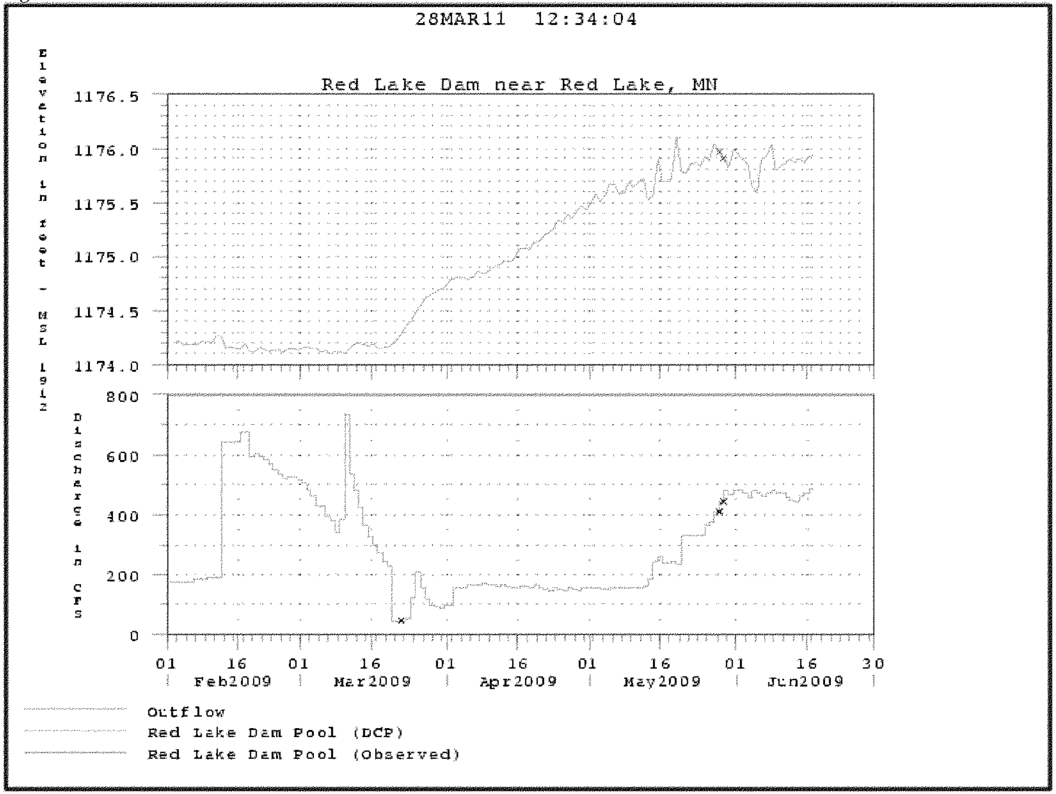


Figure 33. WET Flow Frequency Curve- Comparison WET Regulated vs WET Unregulated

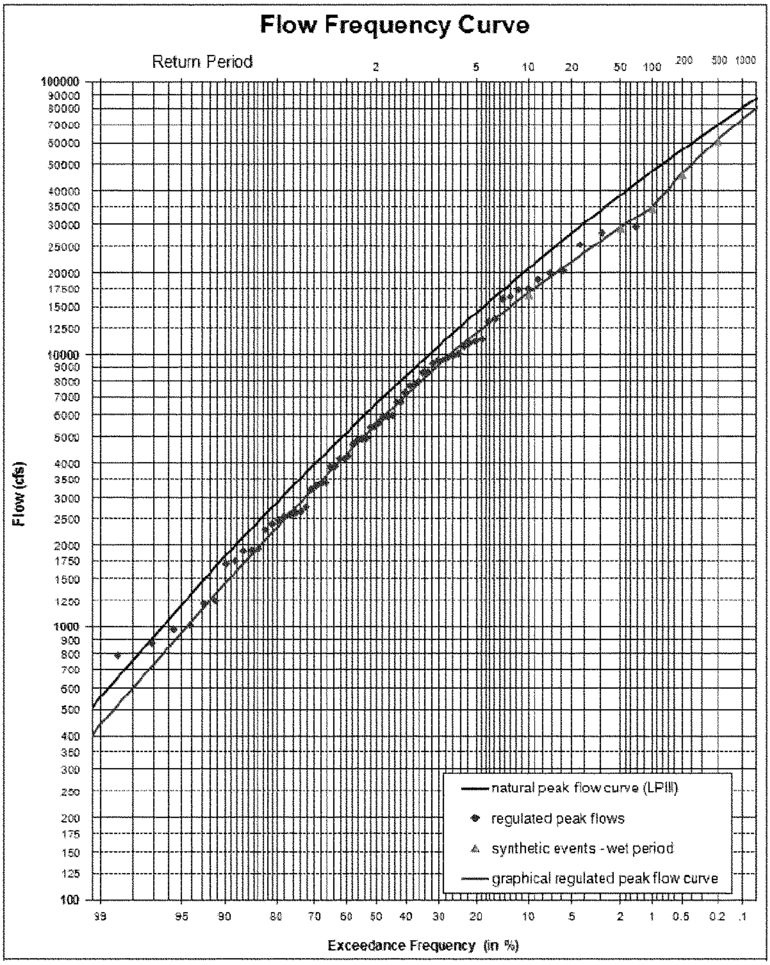


Figure 34. DRY Flow Frequency Curve- Comparison DRY Regulated vs DRY Unregulated

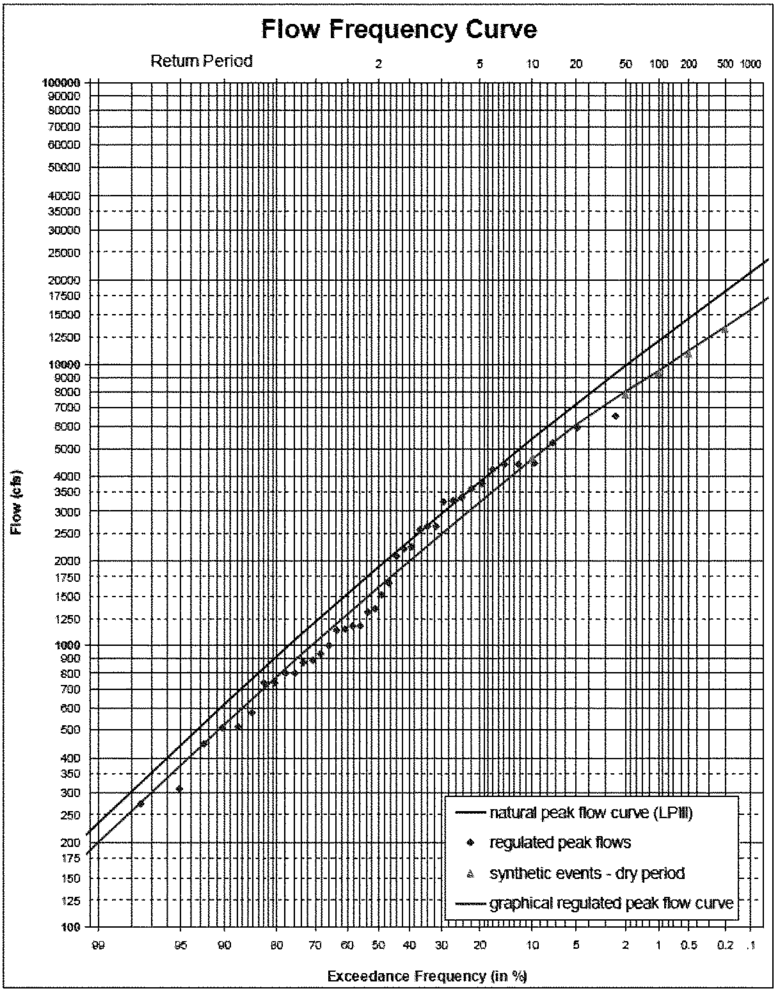


Figure 35- Discharge-Frequency Curve, Red River at Fargo-, Annual Mean Daily Peaks

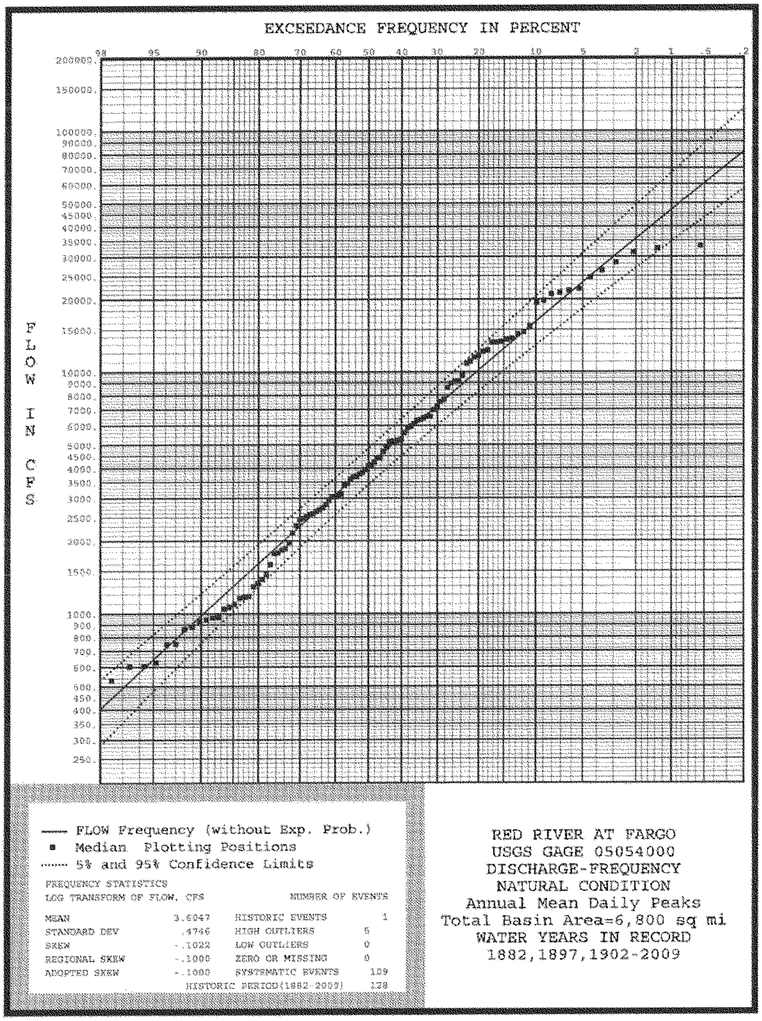


Figure 36- Regression relationship between mean daily and instantaneous peaks for the Red River at Fargo

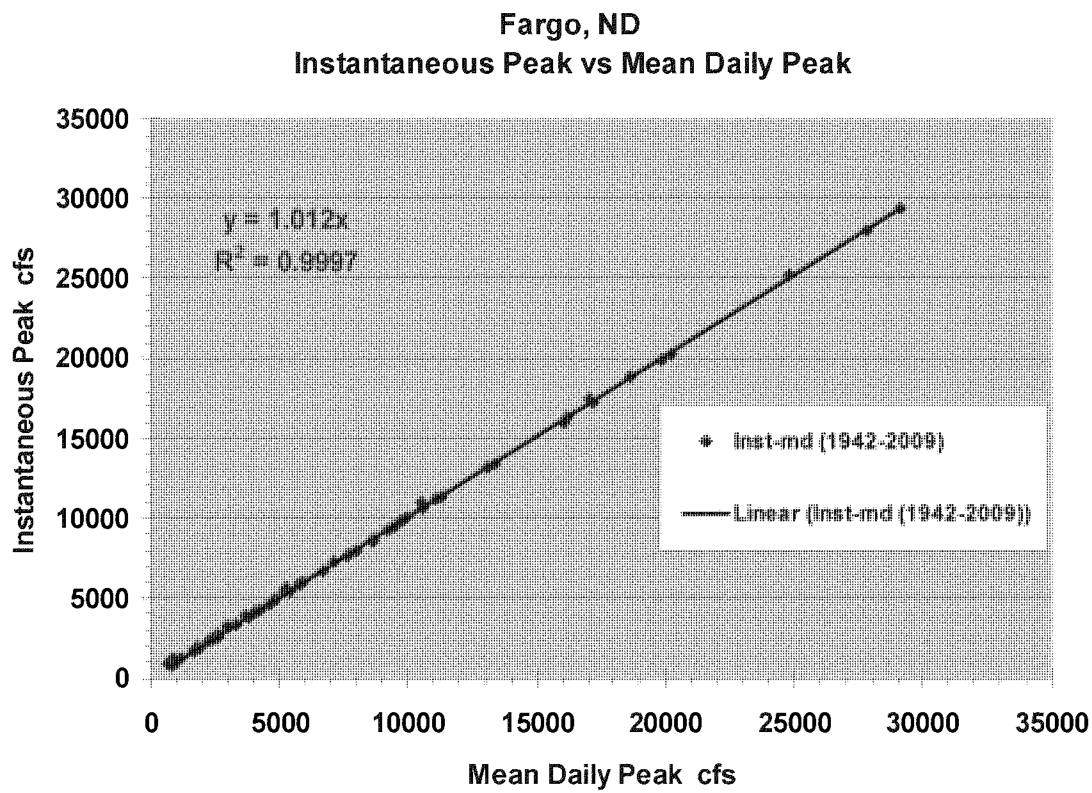


Figure 37- Flow-Frequency Curve: Annual Instantaneous Peaks for the Red River of the North at Fargo

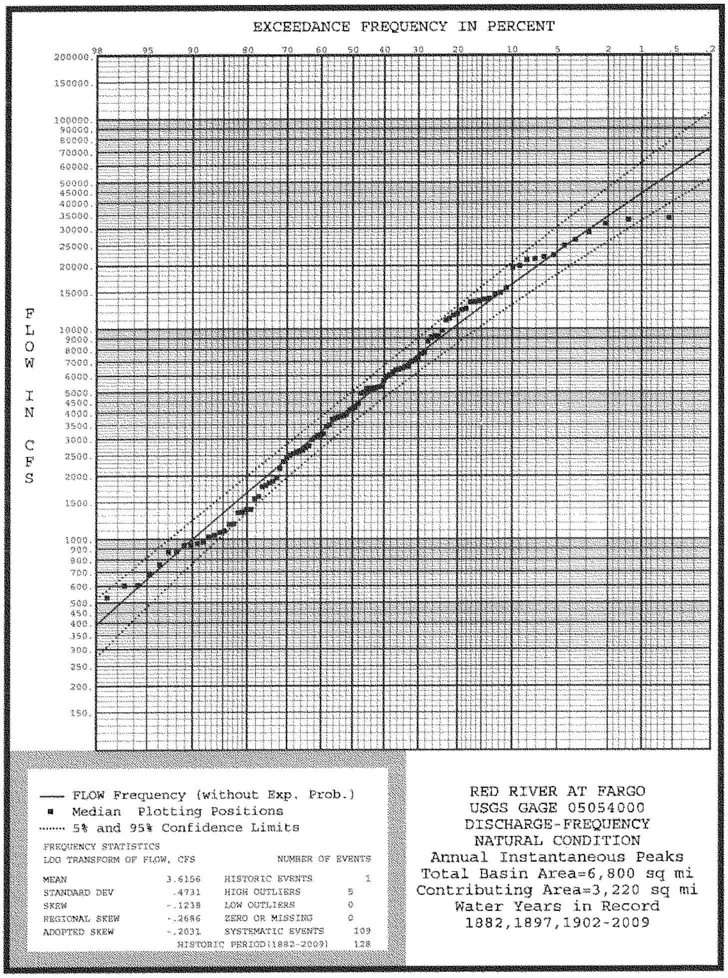


Figure 38-Regression relationship relating regulated and simulated natural mean daily flows for the Red River of the North at Fargo.

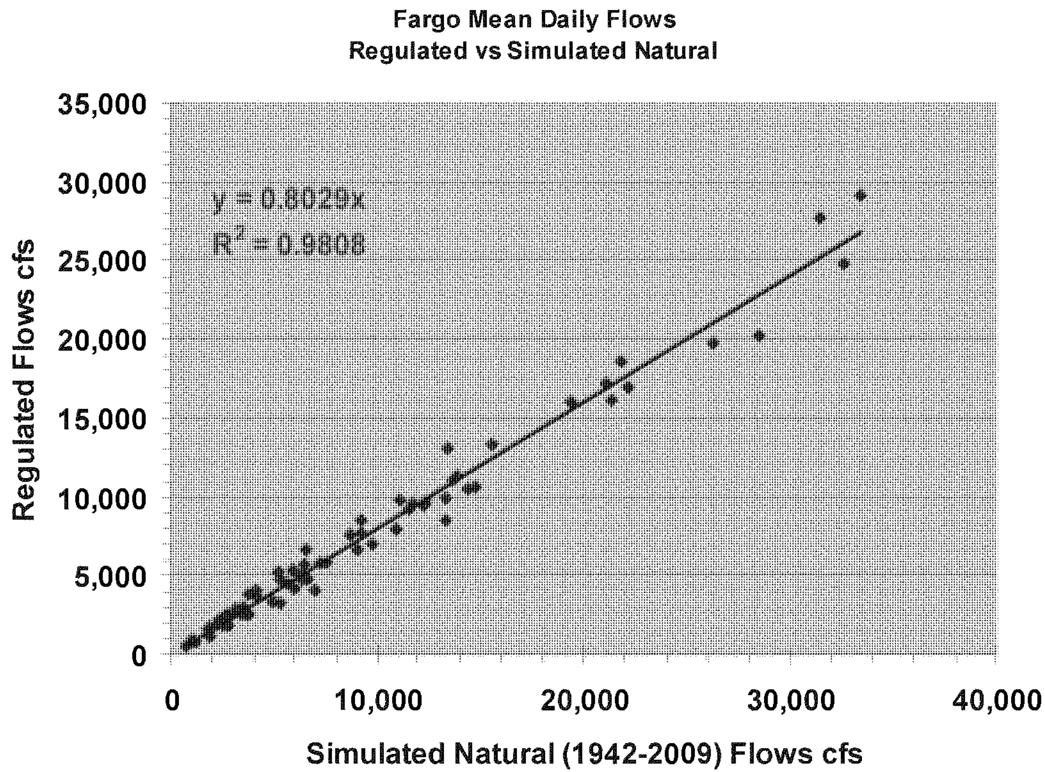


Figure 39- Red River @ Fargo Discharge-Frequency, Regulated, Annual Mean Daily Peaks

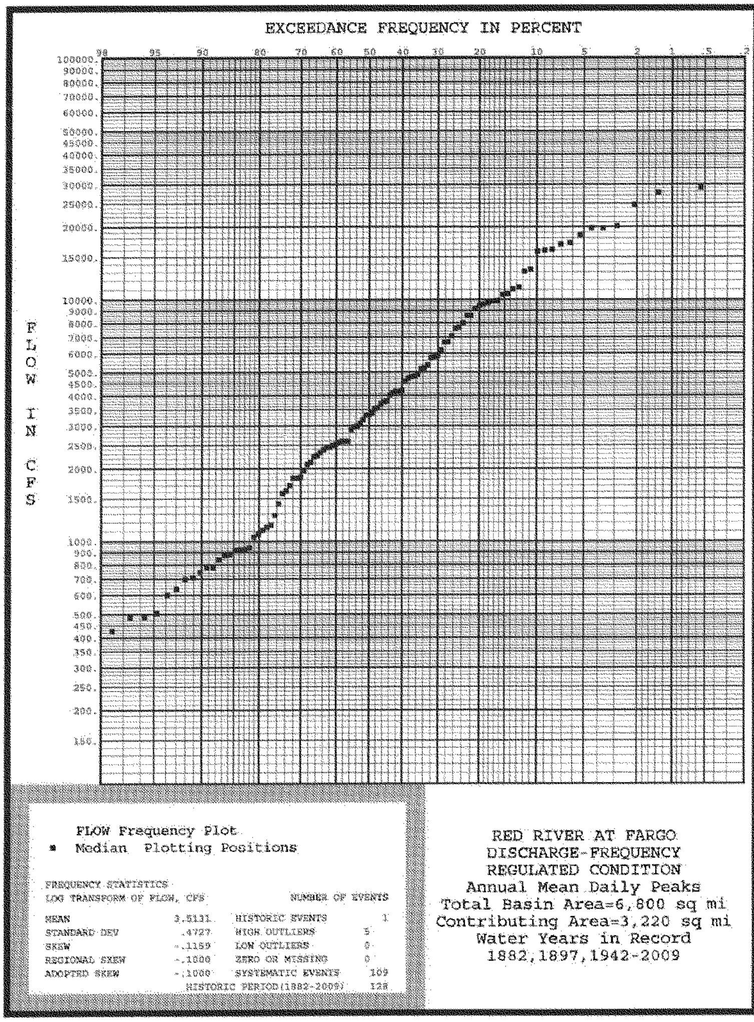
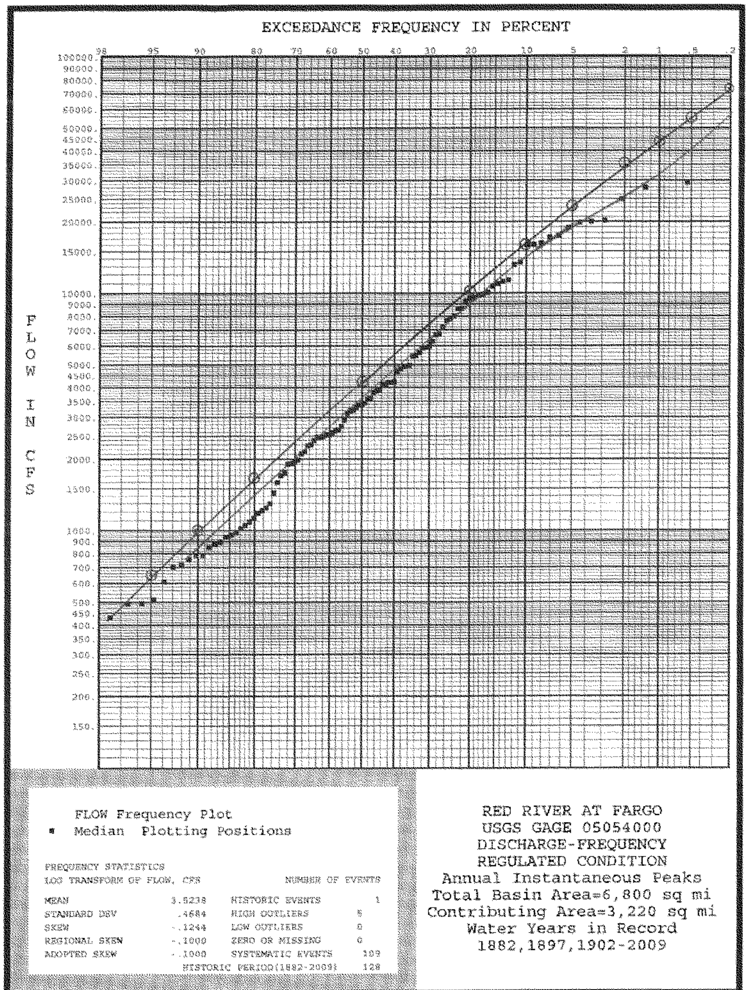


Figure 40- Red River @ Fargo Discharge-Frequency, Regulated Condition, Annual Instantaneous Peaks



Pencil Line = Graphical Flow Frequency Curve

Figure 41- Red River at Wahpeton, ND Two Station Comparison, Discharge-Frequency Curve

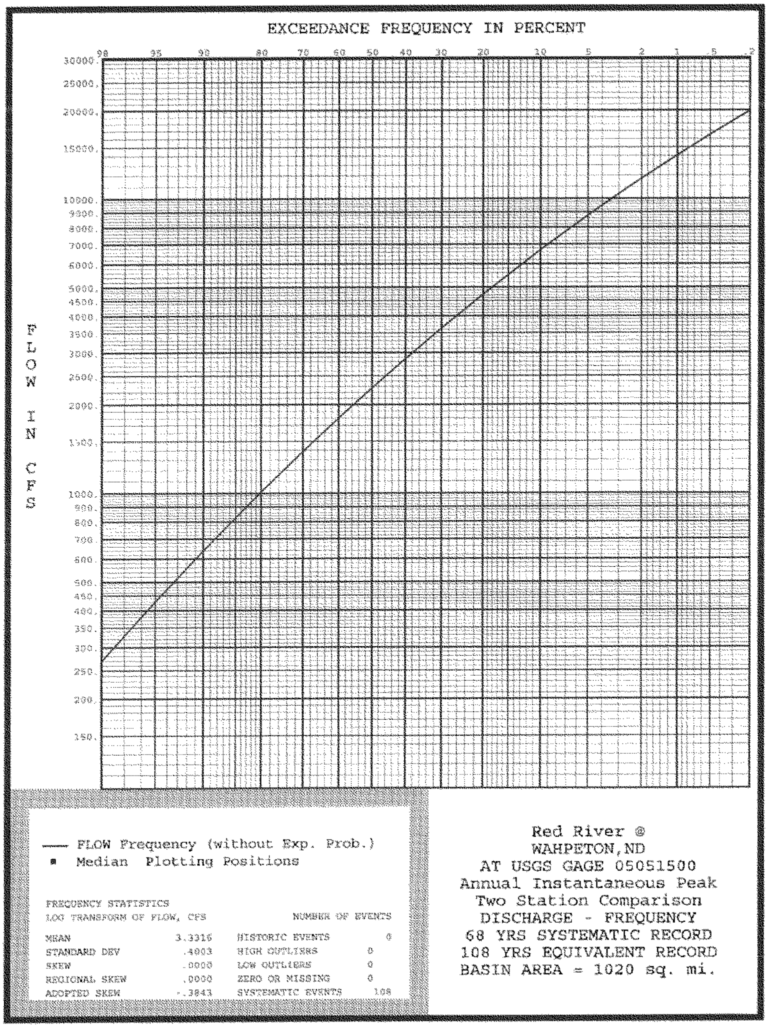


Figure 42. Wahpeton Peak Discharge General Relations for Contributing Drainage Area with Dams but without Breakout

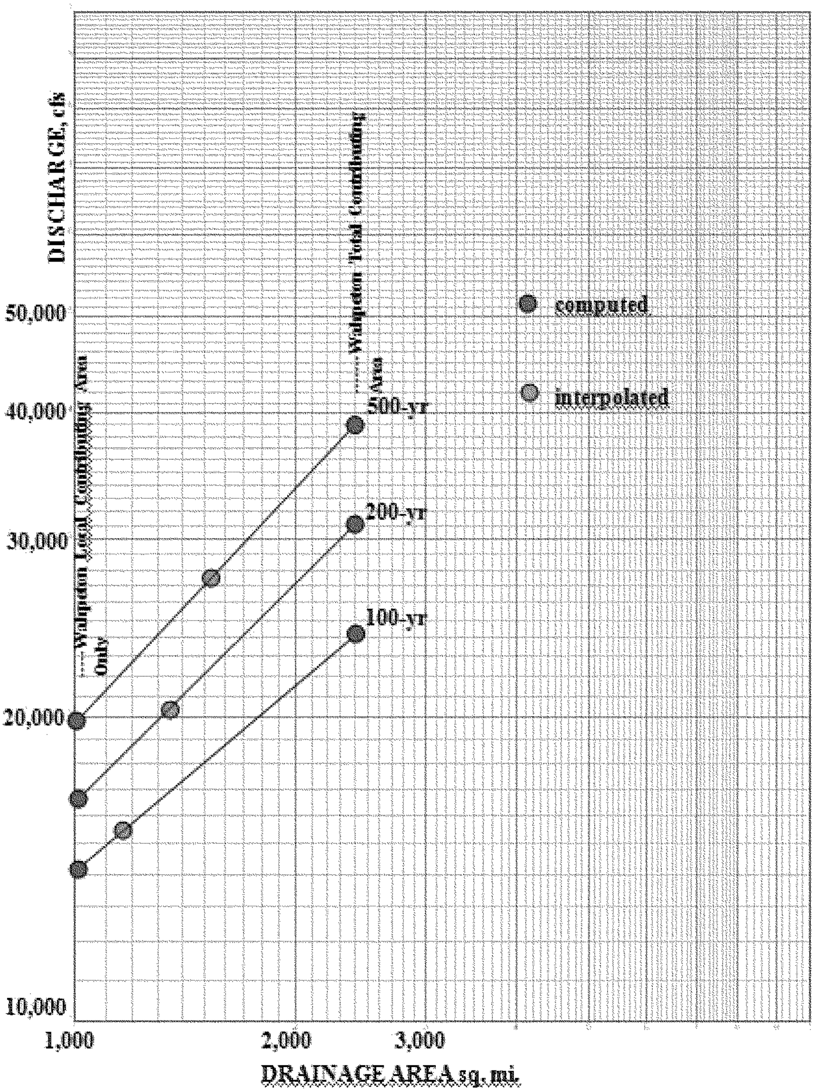


Figure 43- Red River @ Wahpeton, ND, Instantaneous Discharge Frequency

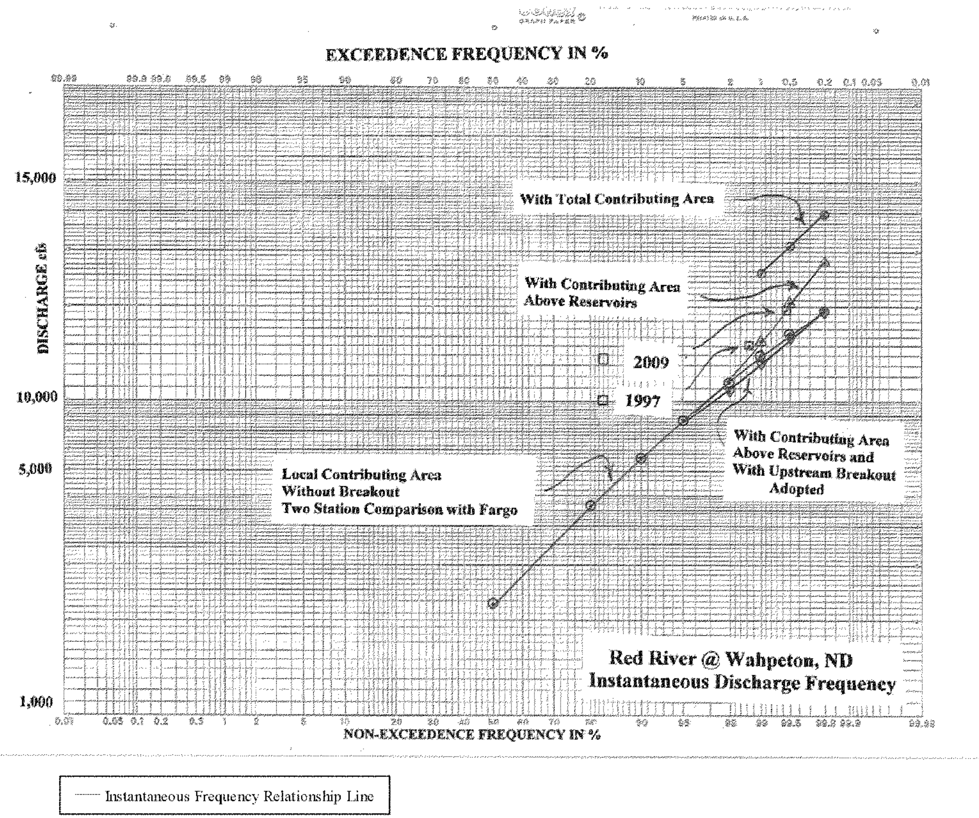
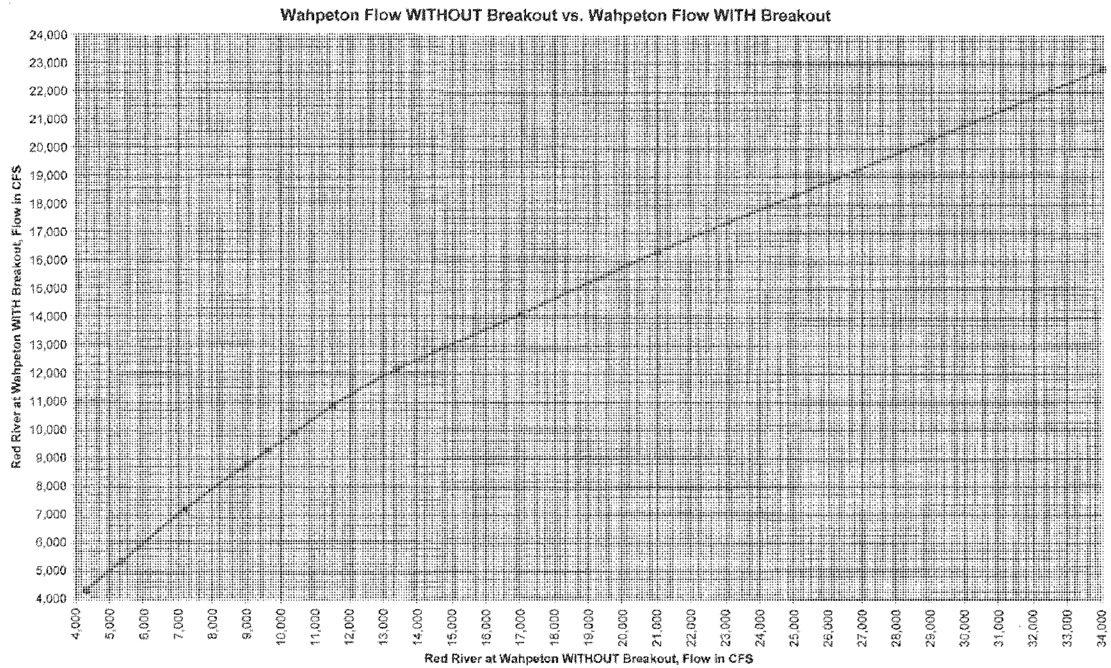
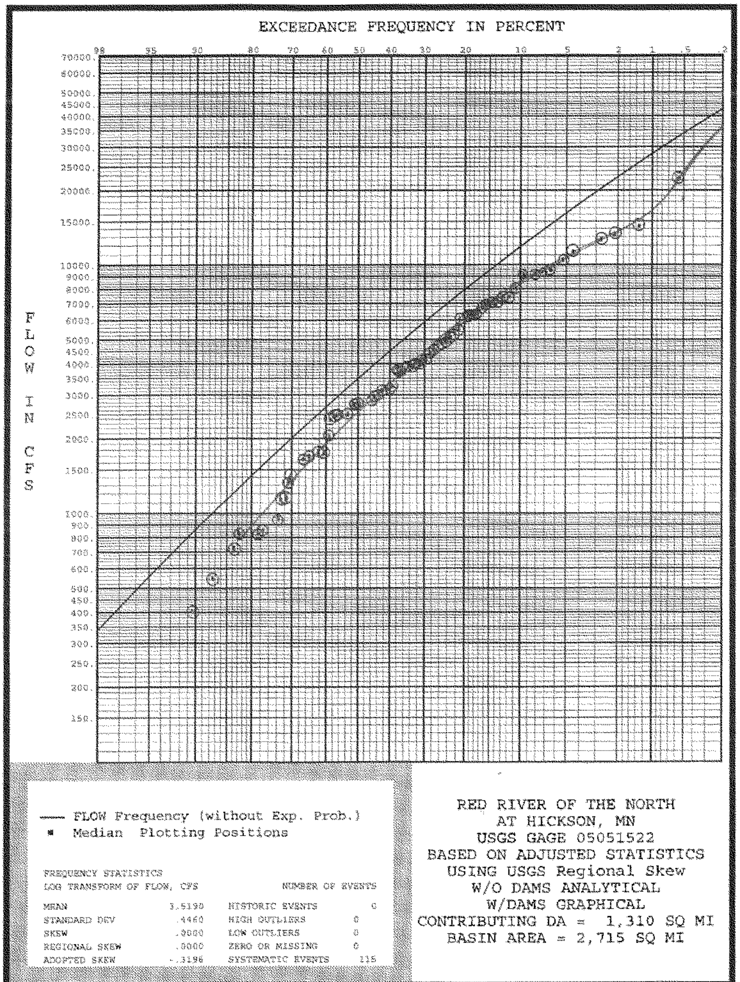


Figure 44- Wahpeton Flow without Breakout vs. Wahpeton Flow with Breakout



Graphical Curve Relating Breakout and Non-breakout Flows at Wahpeton

Figure 45- Red River of the North @ Hickson, Flow- Frequency Curve



Pencil Line = Graphical Flow Frequency Curve

Figure 46- Wild Rice River @ Confluence, Annual Coincident Peaks, Discharge-Frequency

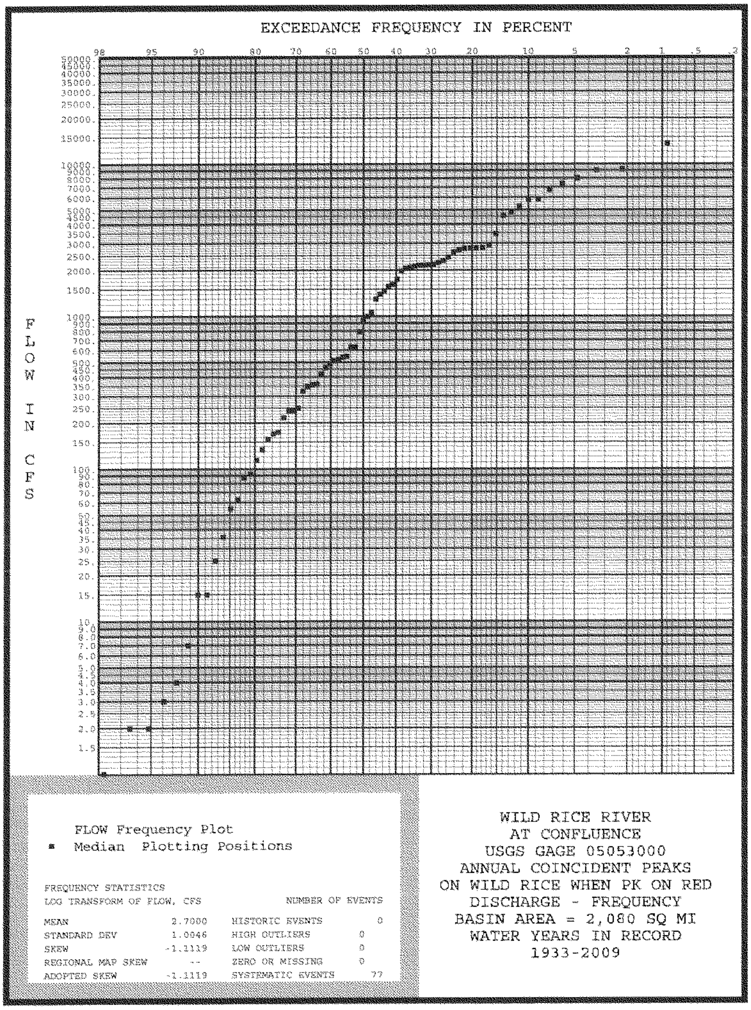
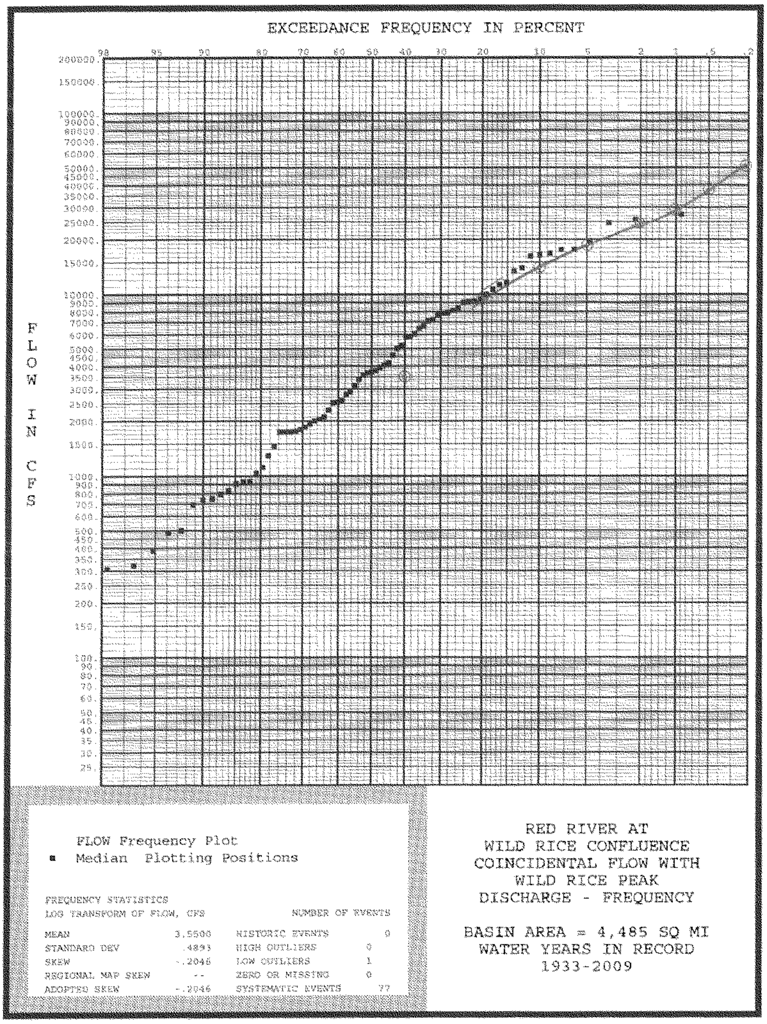


Figure 47- Red River at Wild Rice Confluence, Coincidental Flow with Wild Rice Peak, Discharge-Frequency



Pencil Line = Graphical Flow Frequency Curve

Figure 48- Halstad Discharge- Frequency Curve before Adjustment

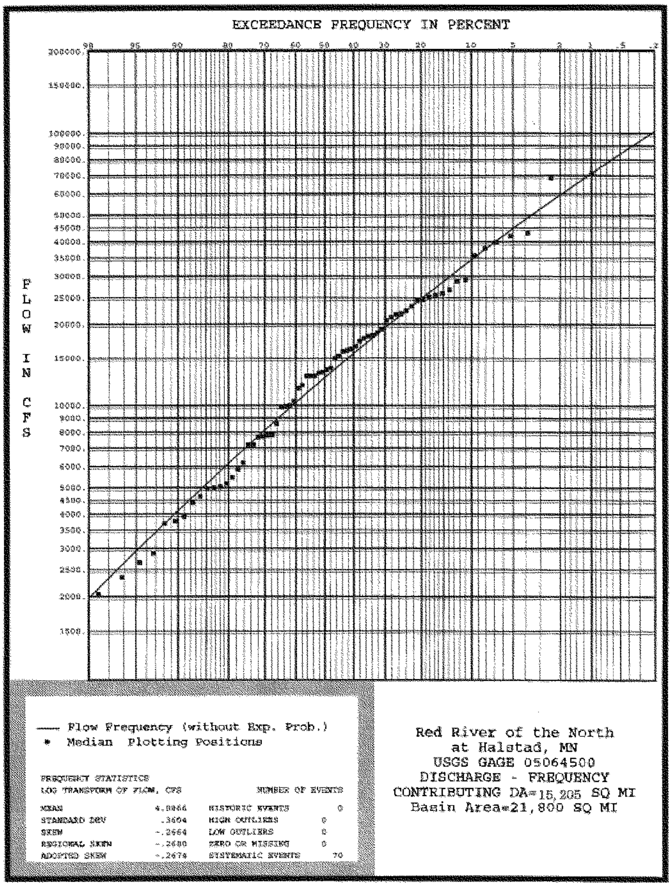


Figure 49- Red River of the North at Halstad, MN, Adjusted, Discharge-Frequency

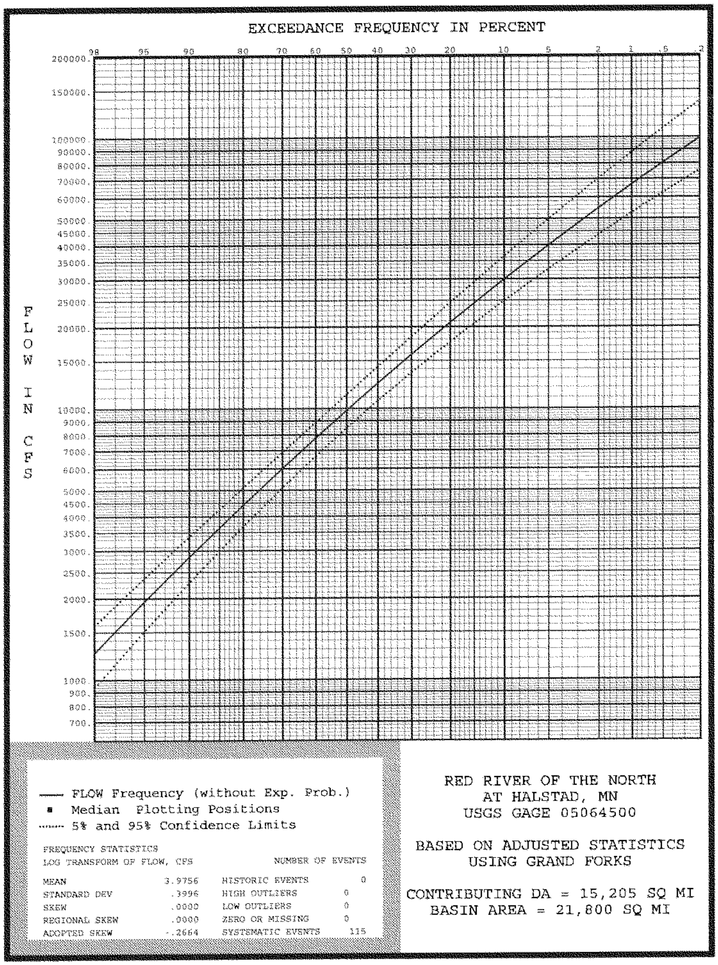


Figure 50- Red River at Grand Forks, Discharge-Frequency

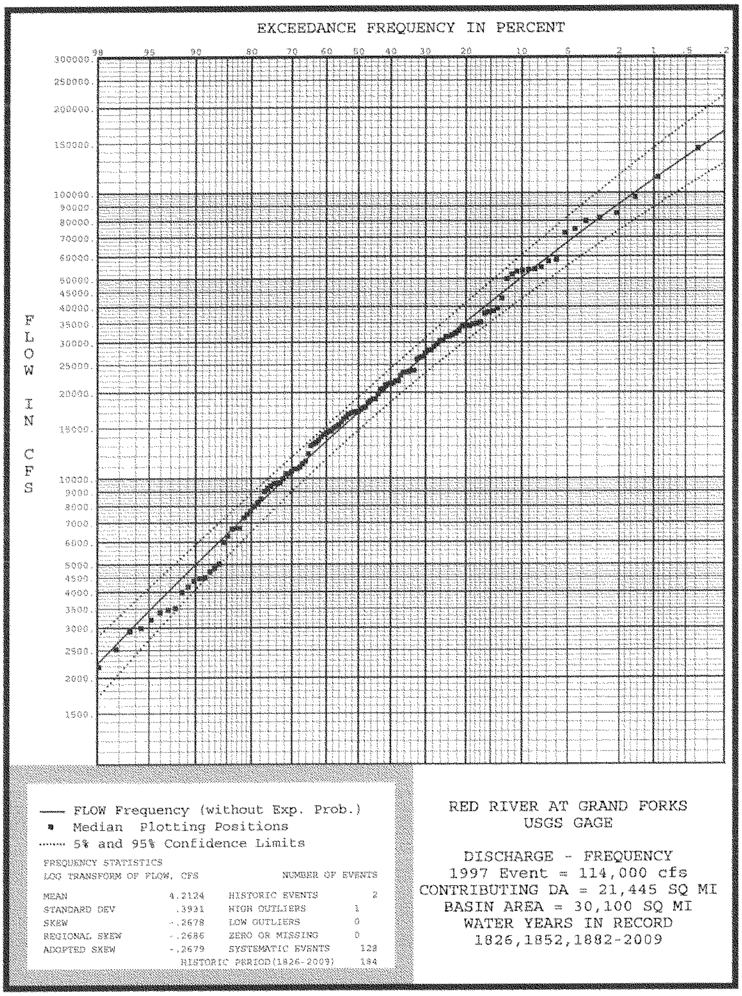


Figure 51- Red River of the North Discharge Frequency Curves

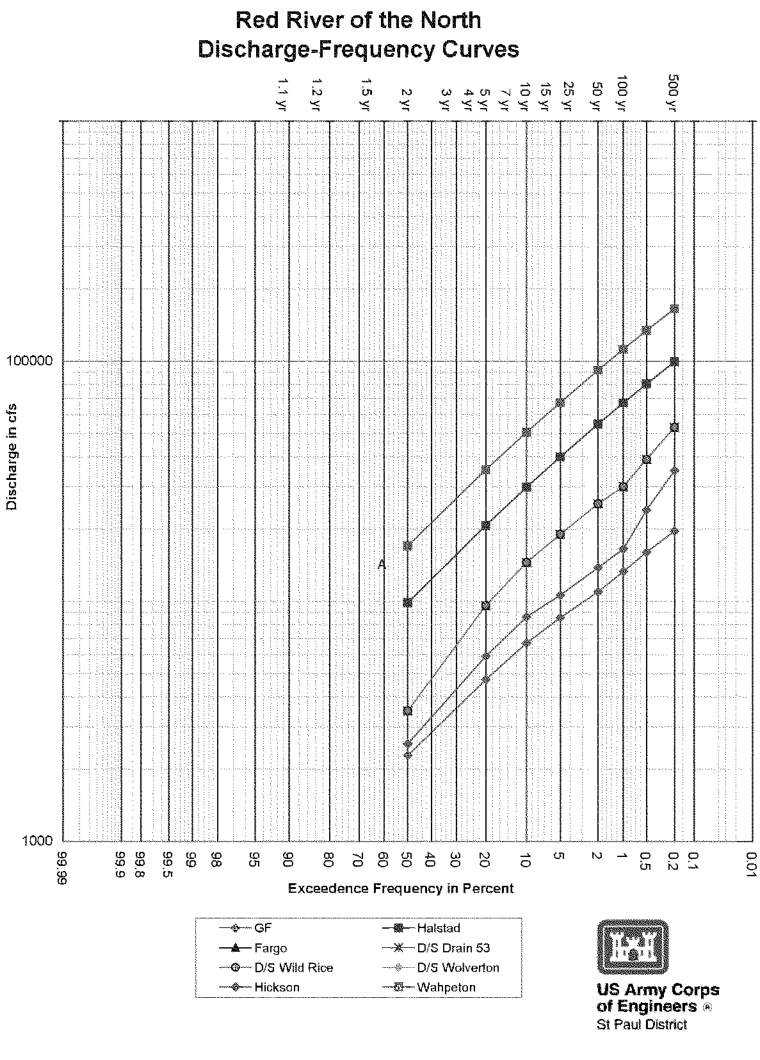
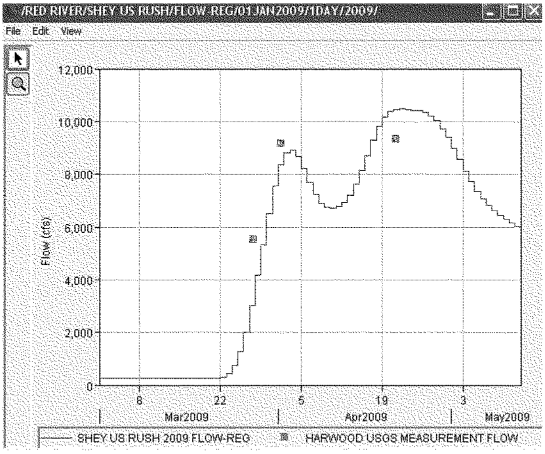


Figure 52- 2009 Event Hydrograph, Sheyenne River at Harwood vs. USGS Readings



1 straddle and 4 day lag from Mapleton to Sheyenne.
5 straddle and 2 day lag from Maple to Rush

Figure 53- 2009 Event Hydrograph, Sheyenne River at Halstad vs. USGS Recorded

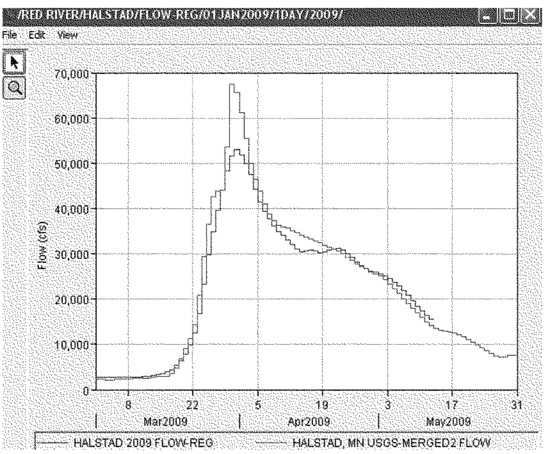
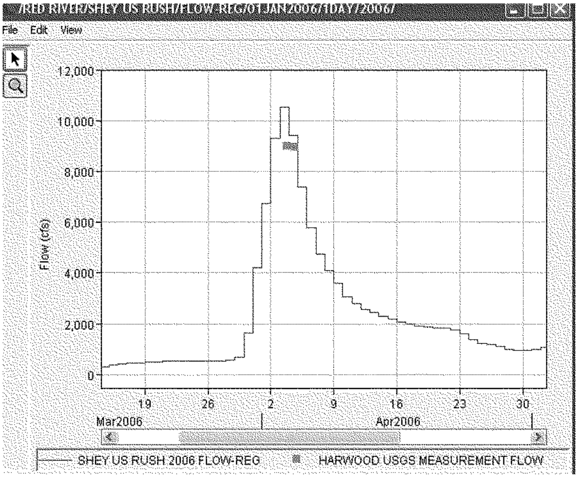


Figure 54-2006 Event Hydrograph, Sheyenne River @ Harwood vs. USGS Readings



2 straddle and 1 day lag from Mapleton to Sheyenne.
1 straddle and 0 day lag from Maple to Rush

Figure 55-2006 Event Hydrograph, Sheyenne River @ Halstad vs. USGS Recorded

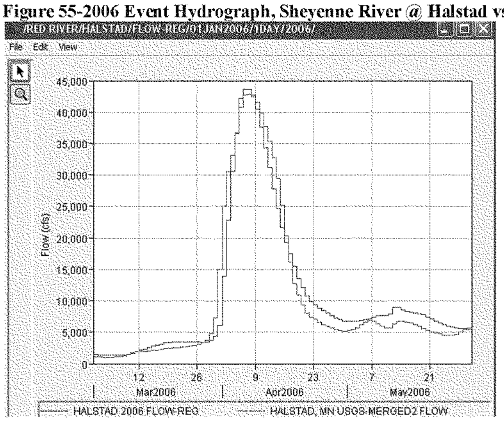
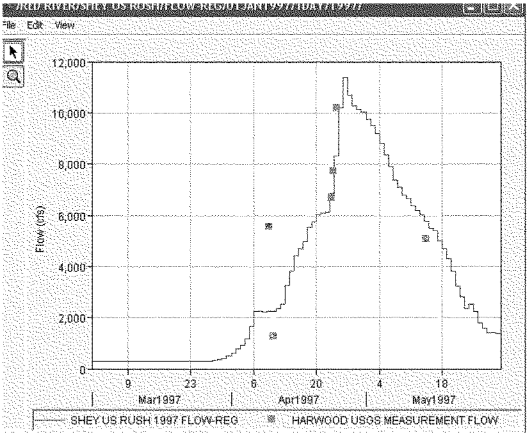


Figure 56- 1997 Event Hydrograph, Sheyenne River @ Harwood vs. USGS Readings



1 straddle and 3 day lag from Mapleton to Sheyenne.
1 straddle and 1 day lag from Maple to Rush

Figure 57- 1997 Event Hydrograph, Sheyenne River @ Halstad vs. USGS Recorded

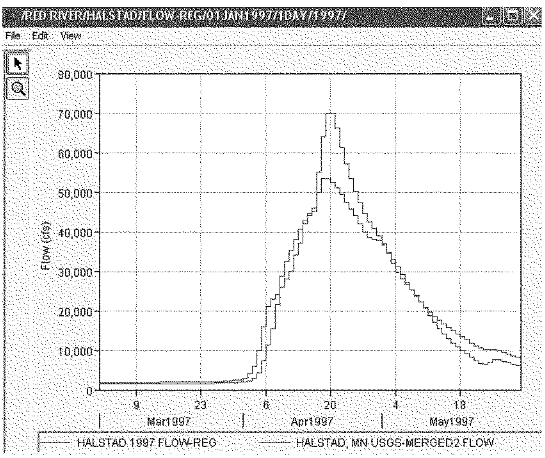


Figure 58- Volume Duration Frequency Analytical Plot for Wahpeton Flood Volume Frequency

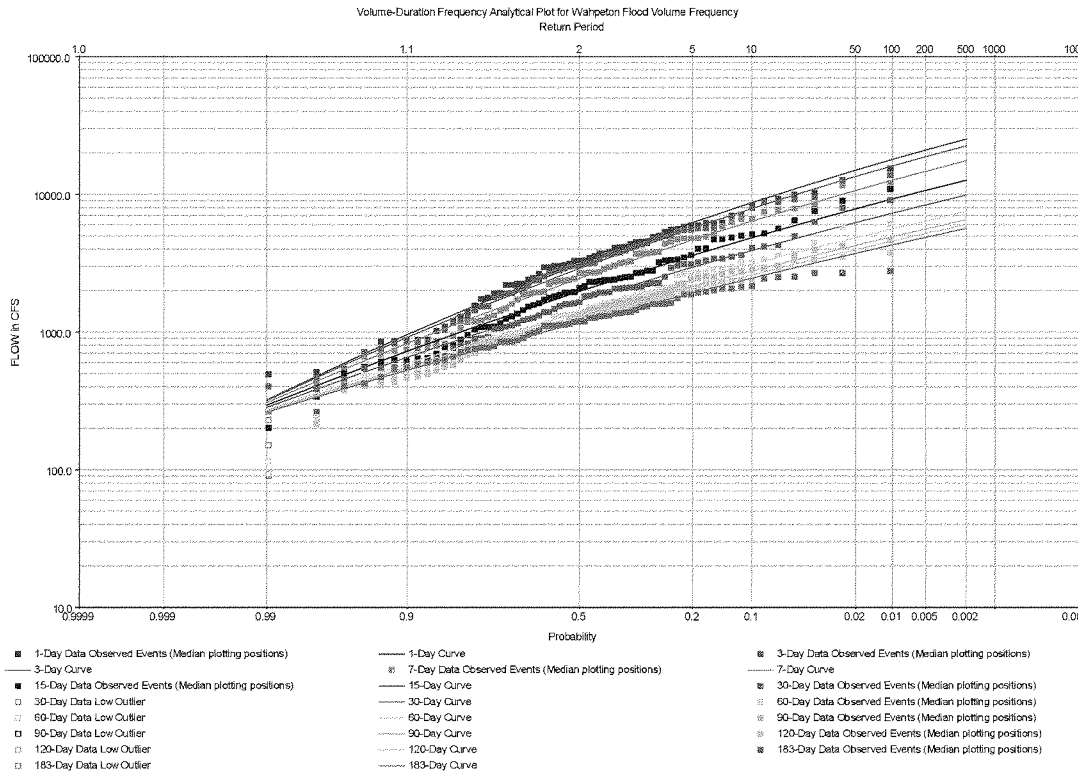


Figure 59- Volume Duration Frequency Analytical Plot for Hickson Flood Volume Frequency

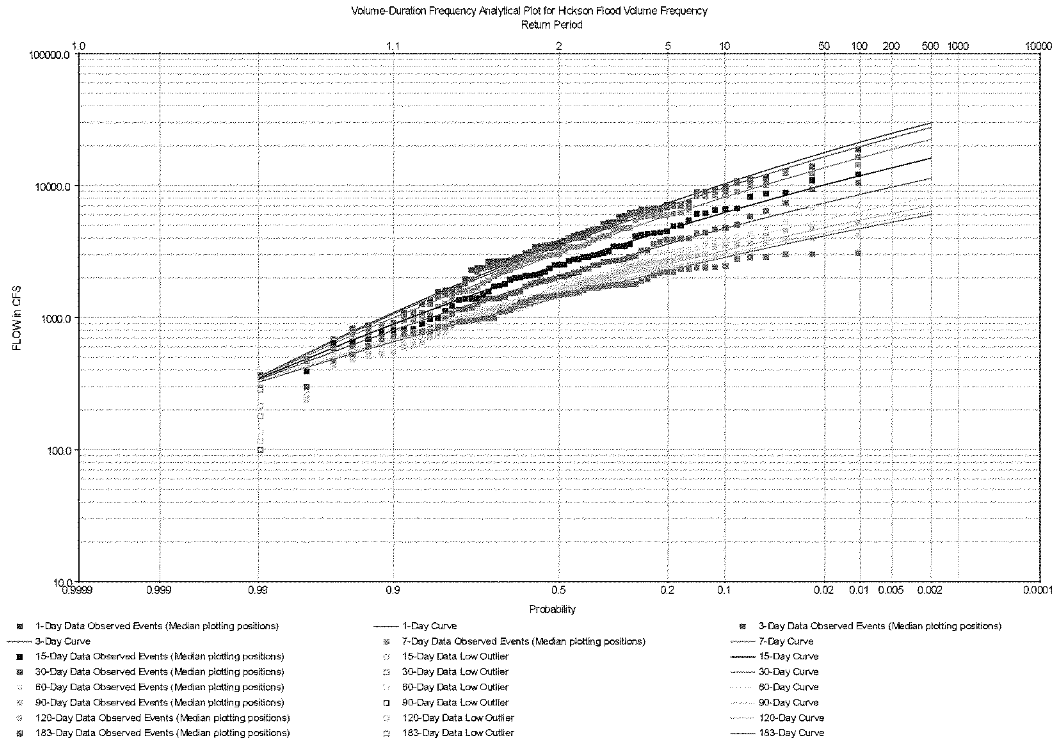


Figure 60- Volume Duration Frequency Analytical Plot for Abercrombie Flood Volume Frequency

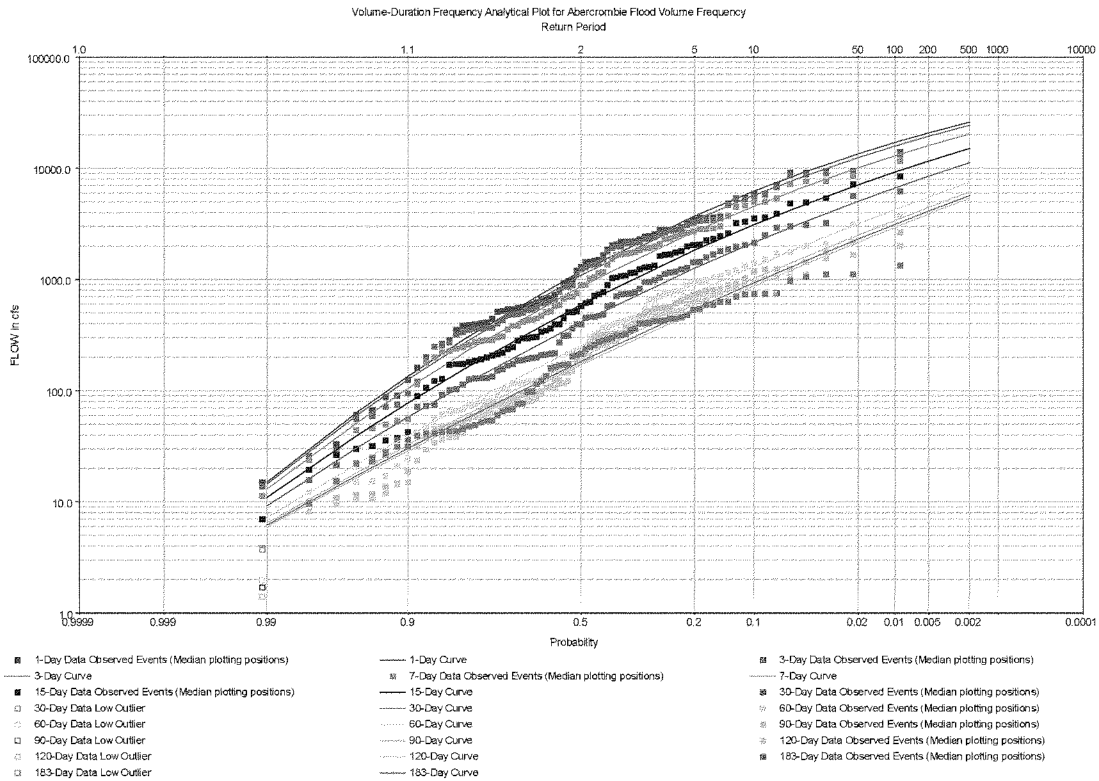


Figure 61- Volume Duration Frequency Analytical Plot for Fargo Flood Volume Frequency

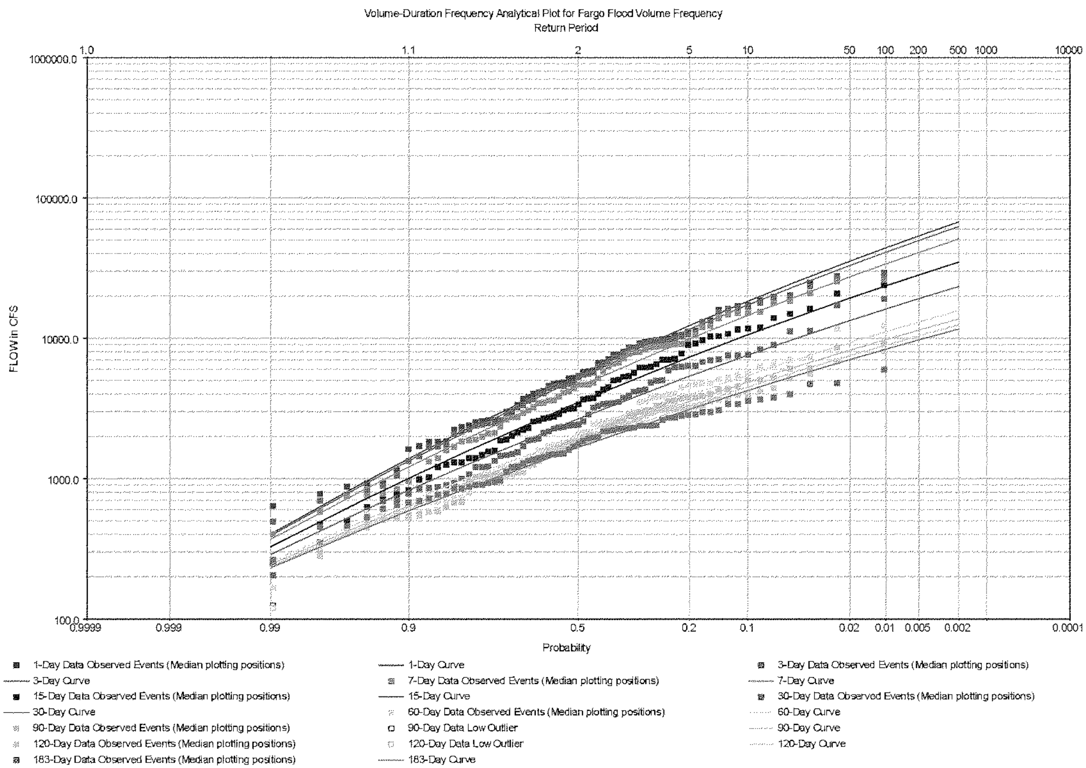


Figure 62- Volume Duration Frequency Analytical Plot for Dilworth Flood Volume Frequency

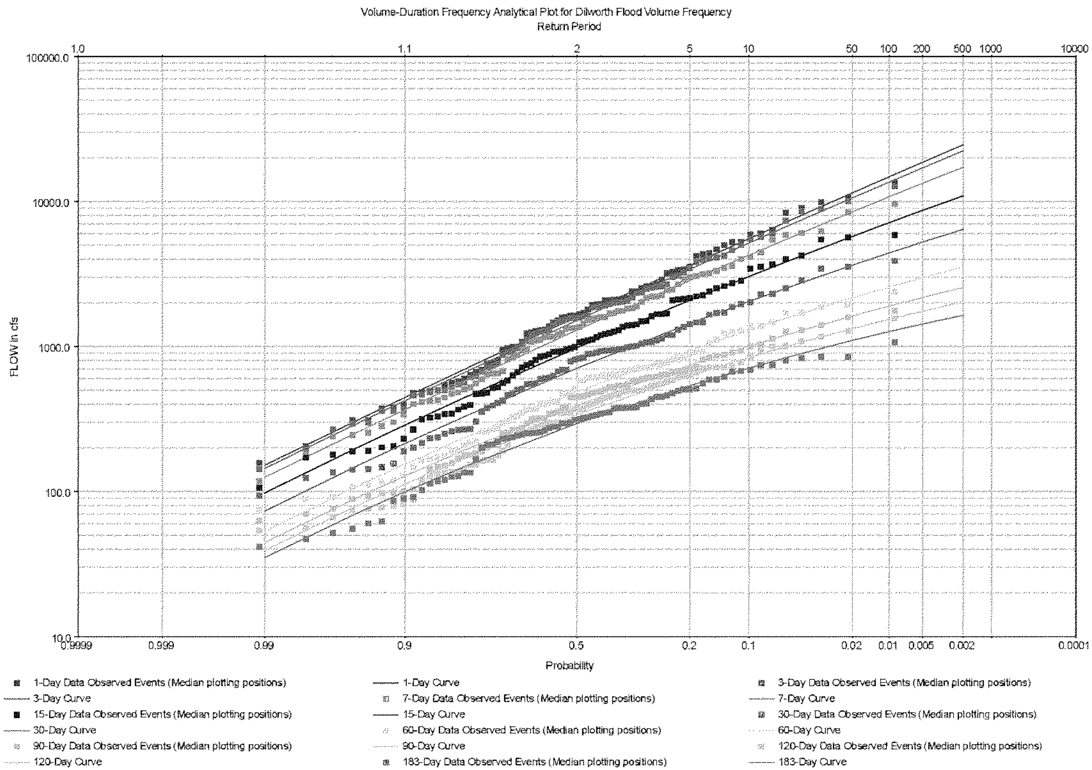


Figure 63- Volume Duration Frequency Analytical Plot for Hendrum Flood Volume Frequency

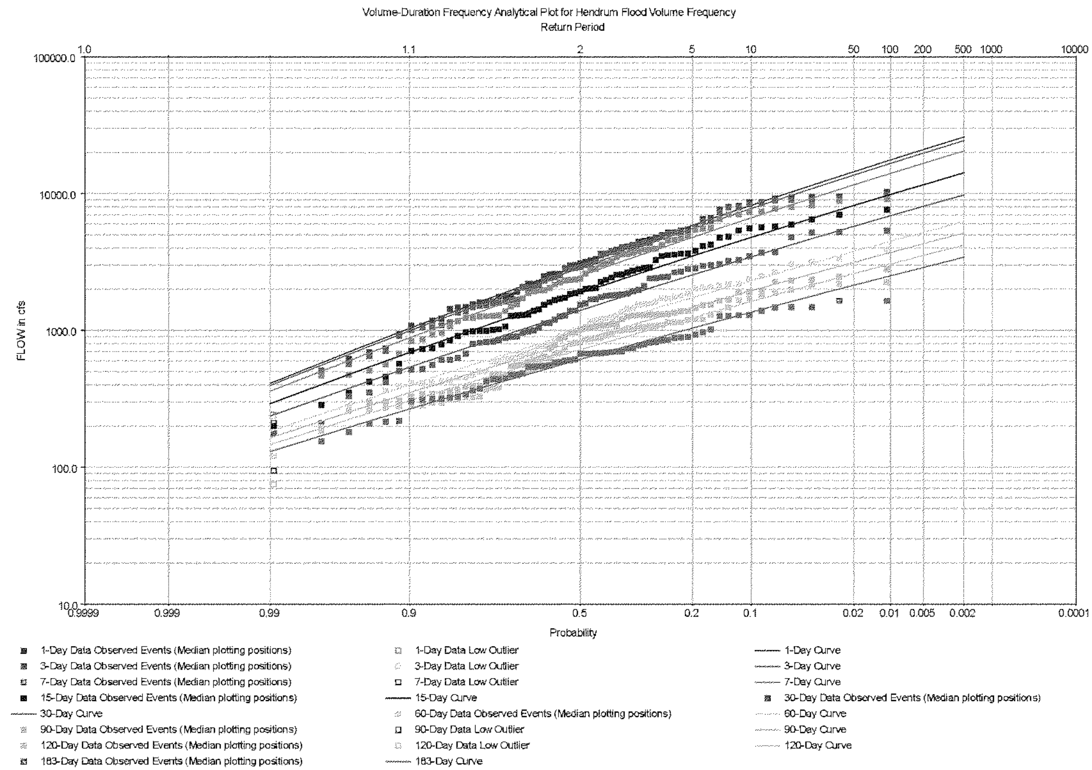
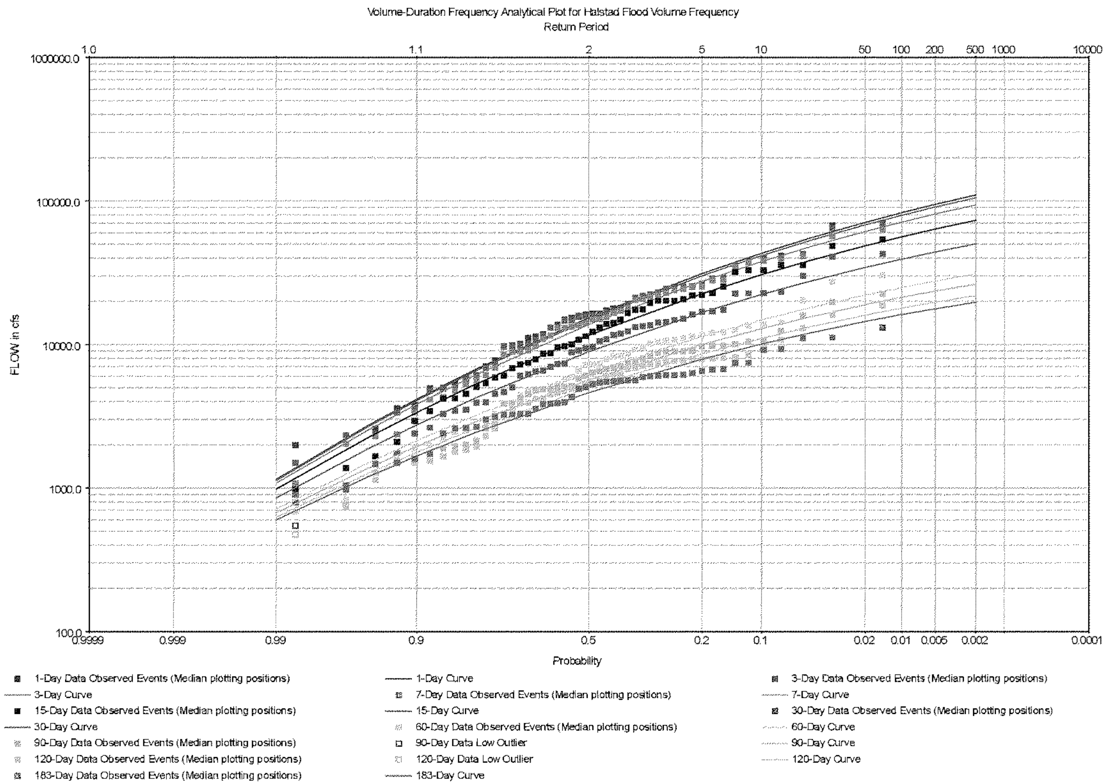


Figure 64- Volume Duration Frequency Analytical Plot for Halstad Flood Volume Frequency



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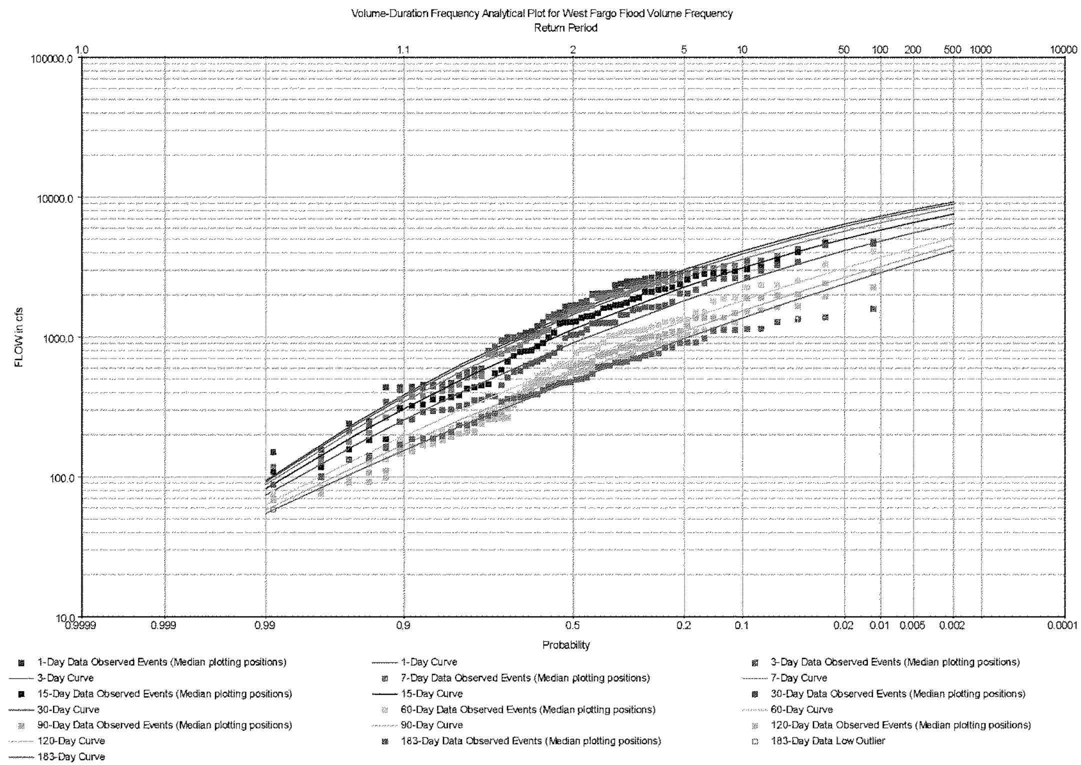


Figure 66- Red river @ Wahpeton Flow Volume-Frequency Curves

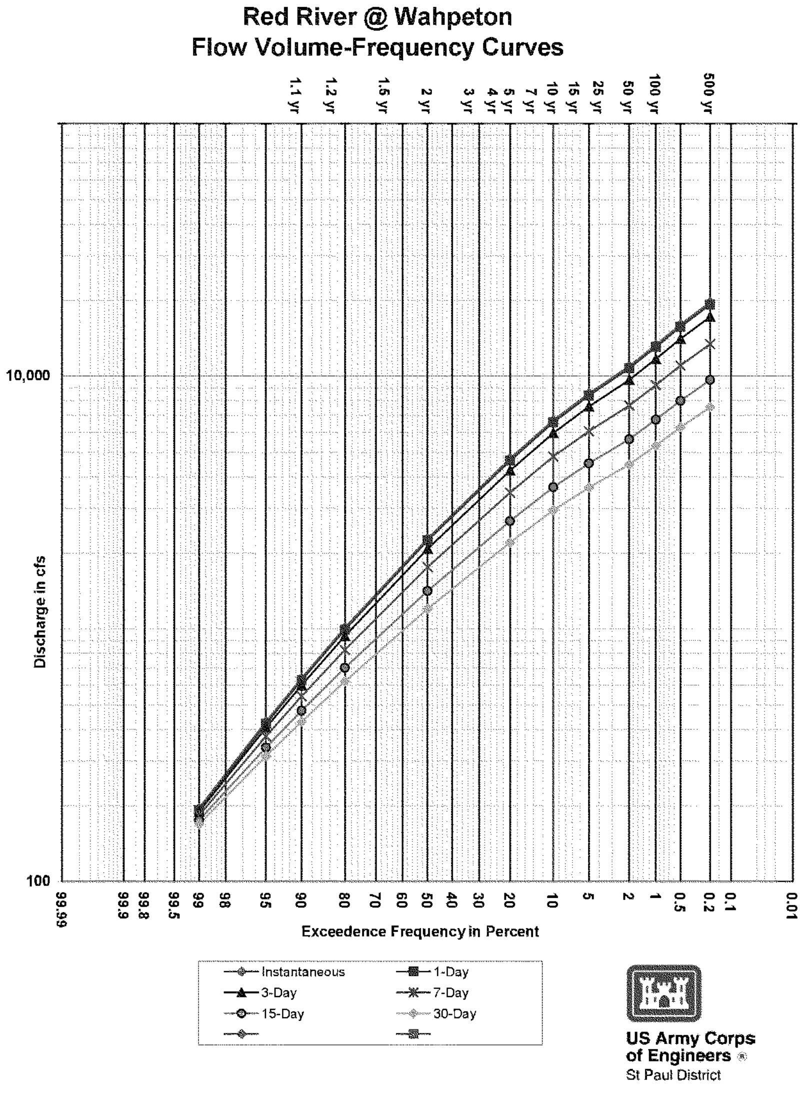


Figure 67- Red River @ Hickson Flow Volume Frequency Curves

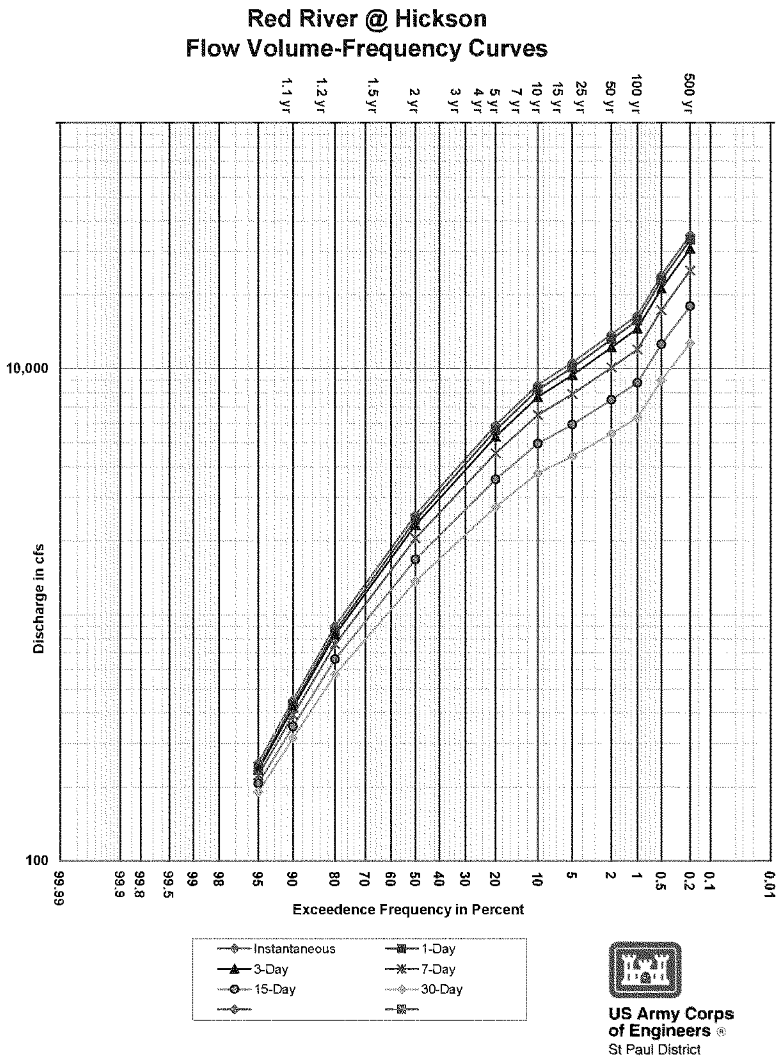
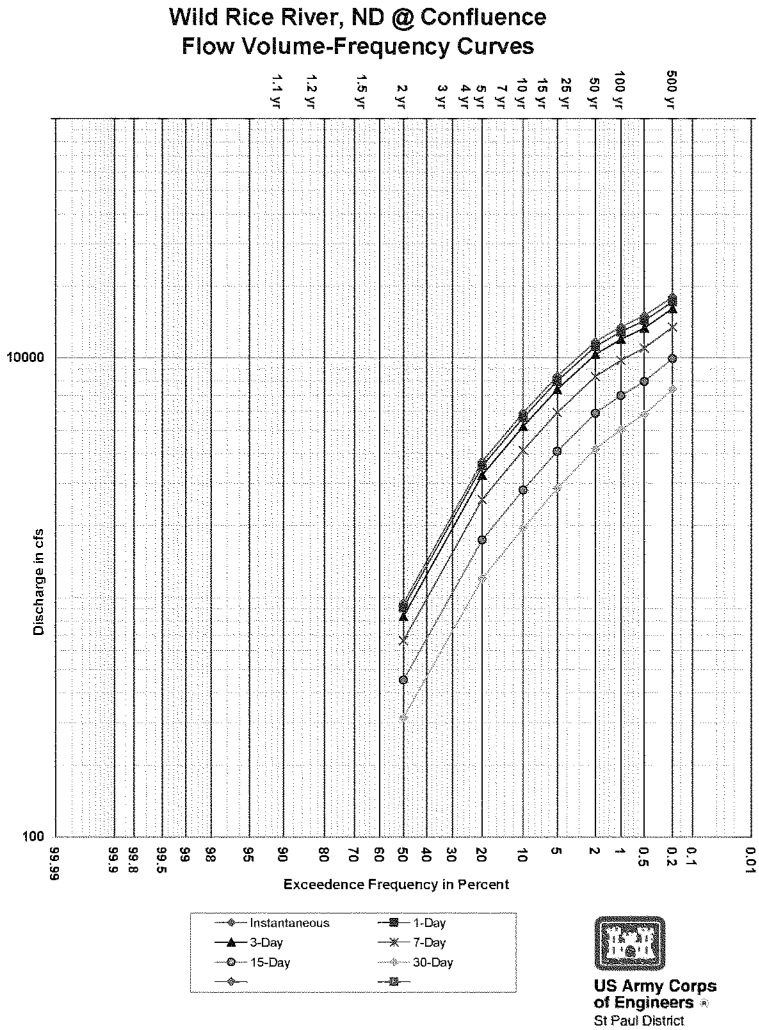


Figure 68- Wild Rice River @ Confluence Flow Volume Frequency Curves



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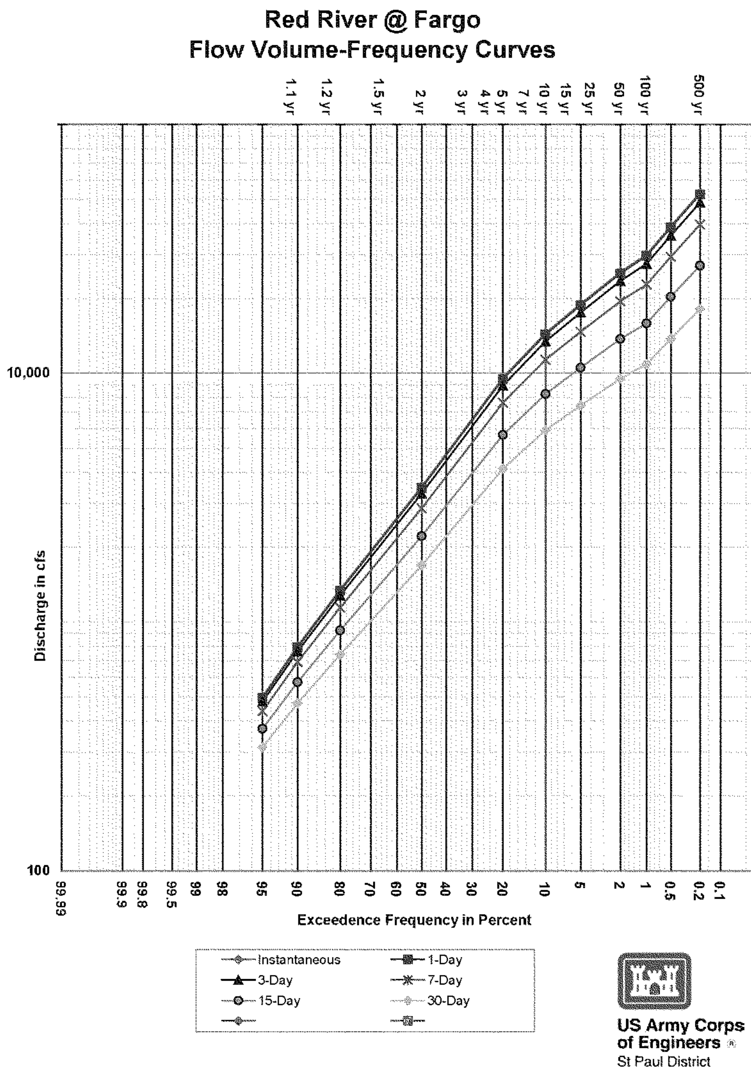


Figure 70- Red River upstream of Sheyenne River Flow Volume Frequency Curves

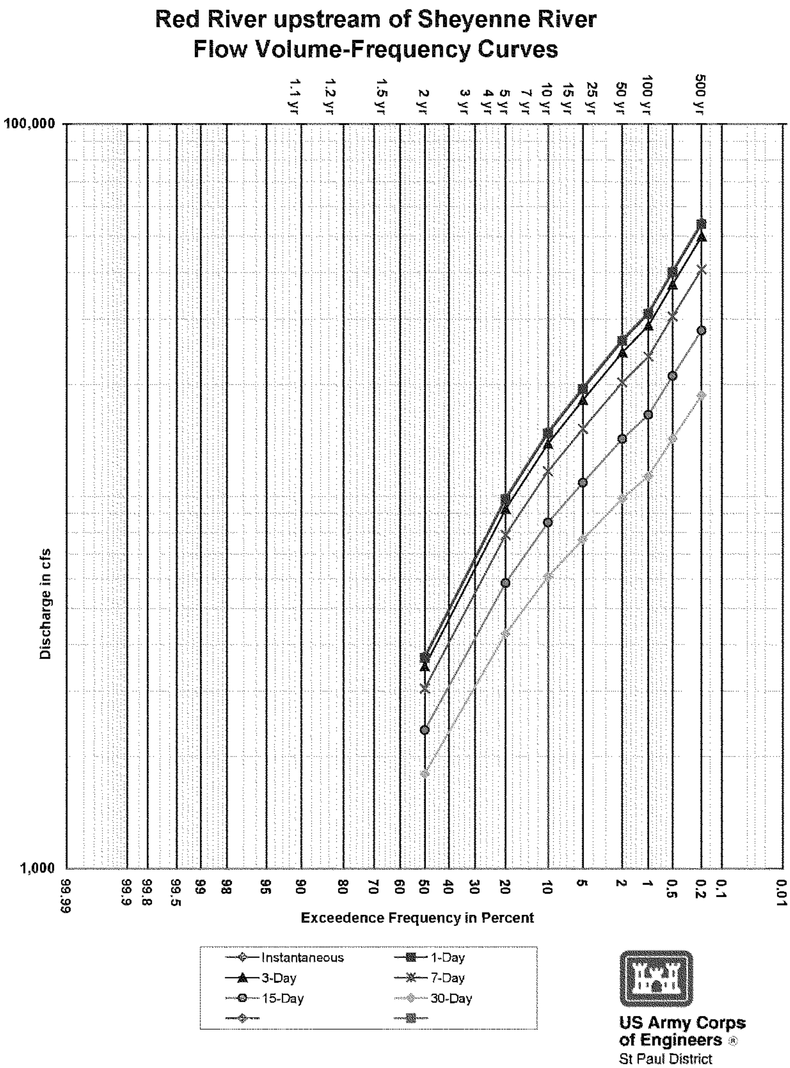


Figure 71- Red River Downstream of Sheyenne River Flow Volume Frequency Curves

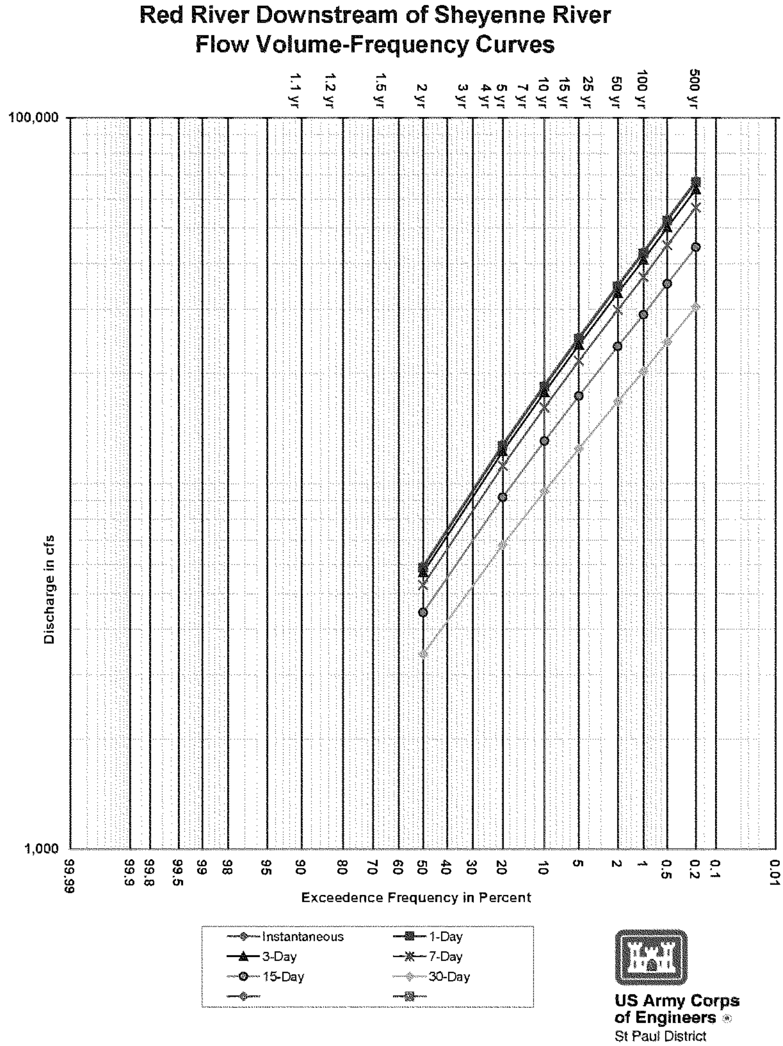


Figure 72- Red River Downstream of Buffalo River, Flow Volume-Frequency Curves

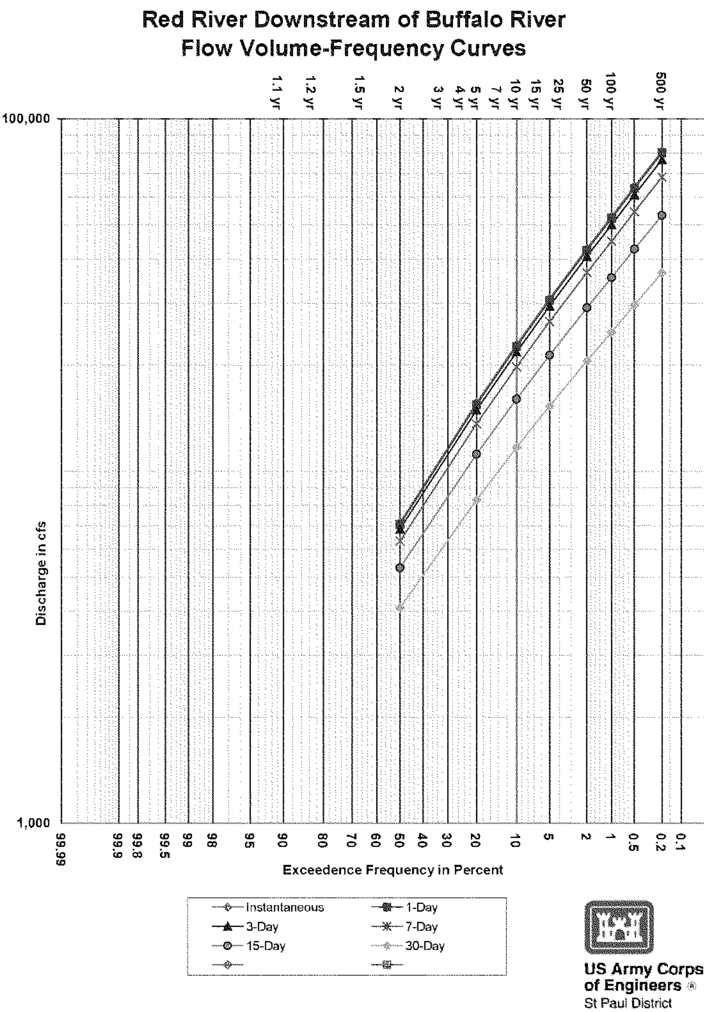


Figure 73- Buffalo River @ Dilworth, Flow Volume-Frequency Curve

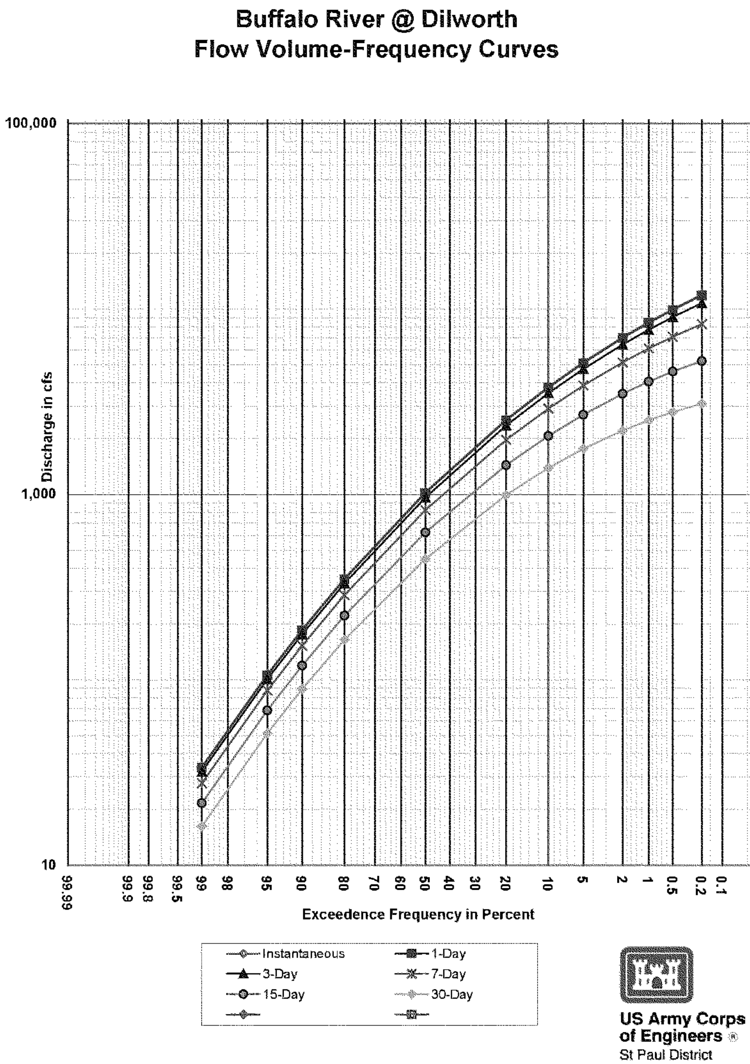


Figure 74- Buffalo River @ Buffalo Confluence, Flow Volume-Frequency Curves

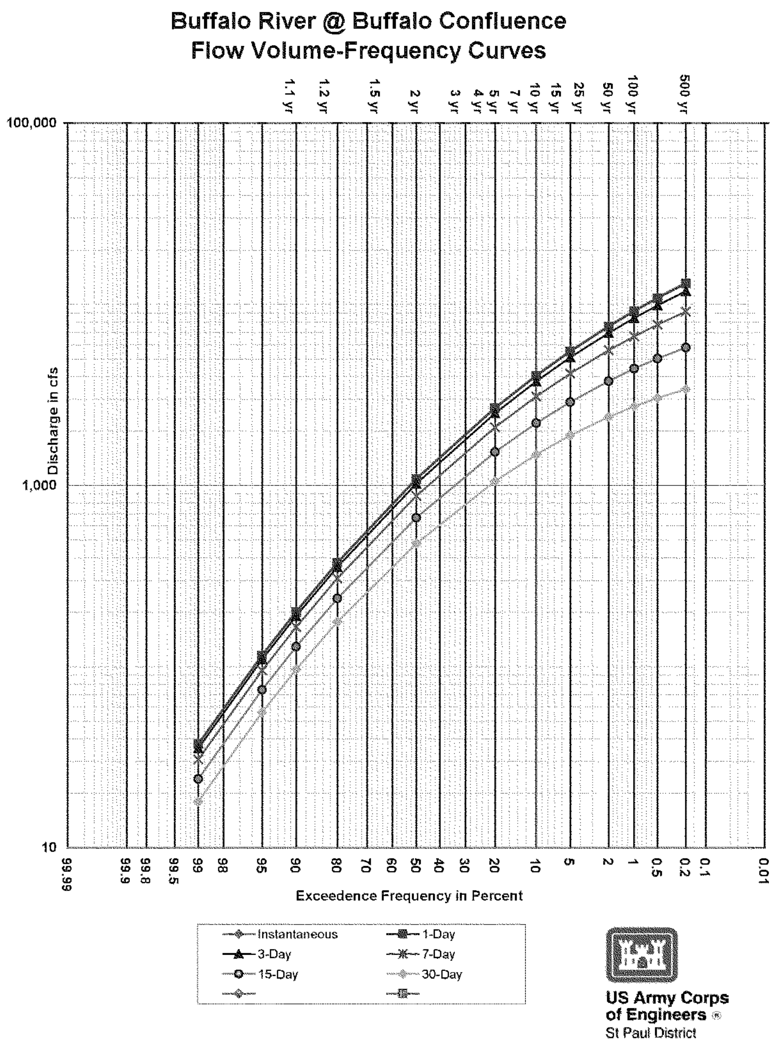


Figure 75- Red River Downstream of Wild Rice River, MN Flow Volume-Frequency Curves

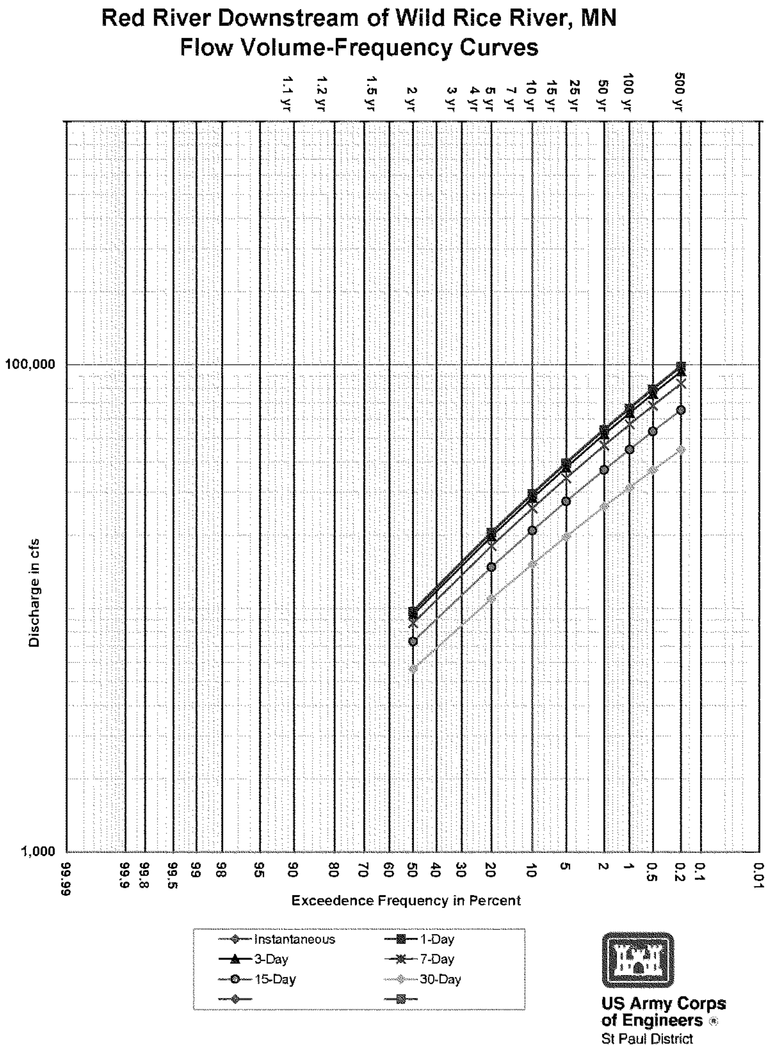


Figure 76- Red River @ Halstad, Flow Volume-Frequency Curves

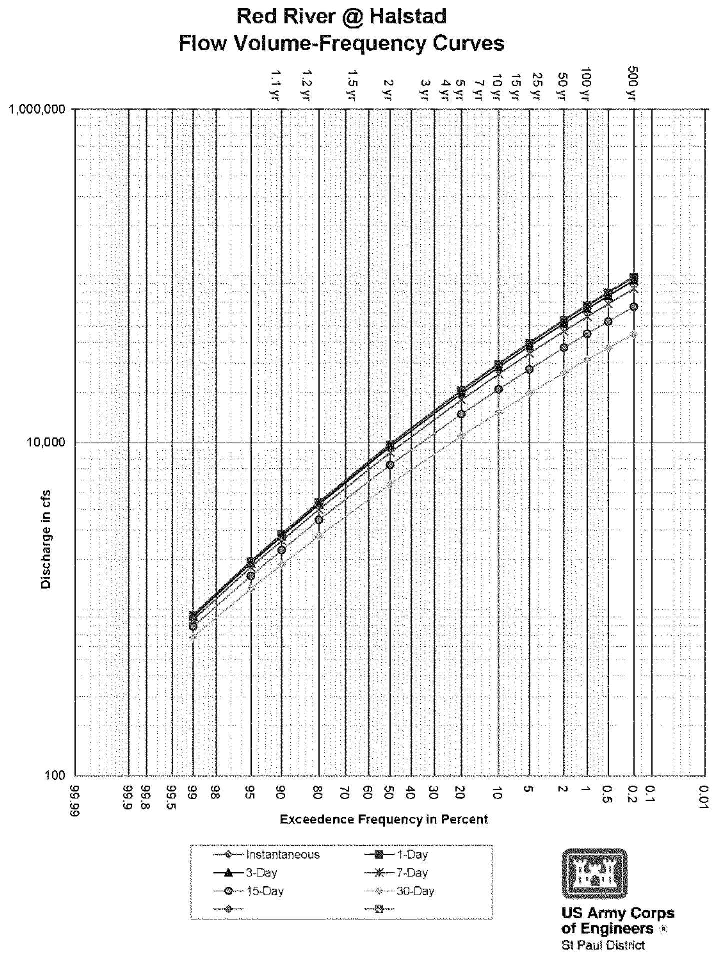


Figure 77- Wild Rice River @ Hendrum Flow Volume-Frequency Curves

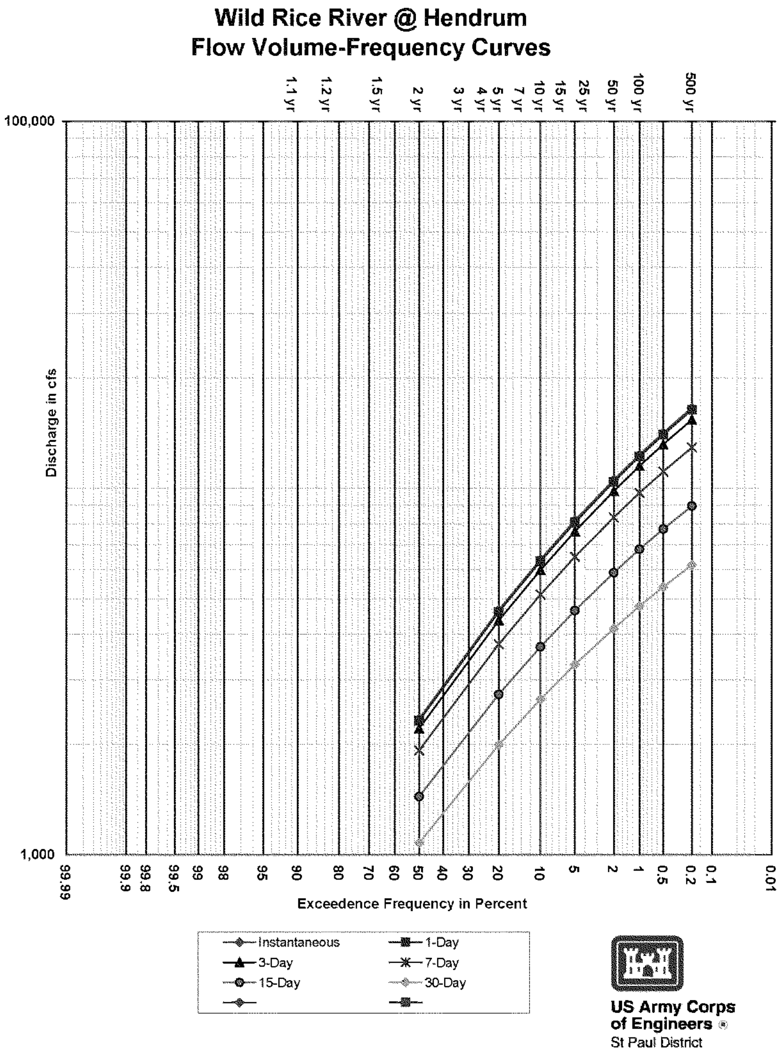


Figure 78- Sheyenne River @ Confluence Flow Volume-Frequency Curves

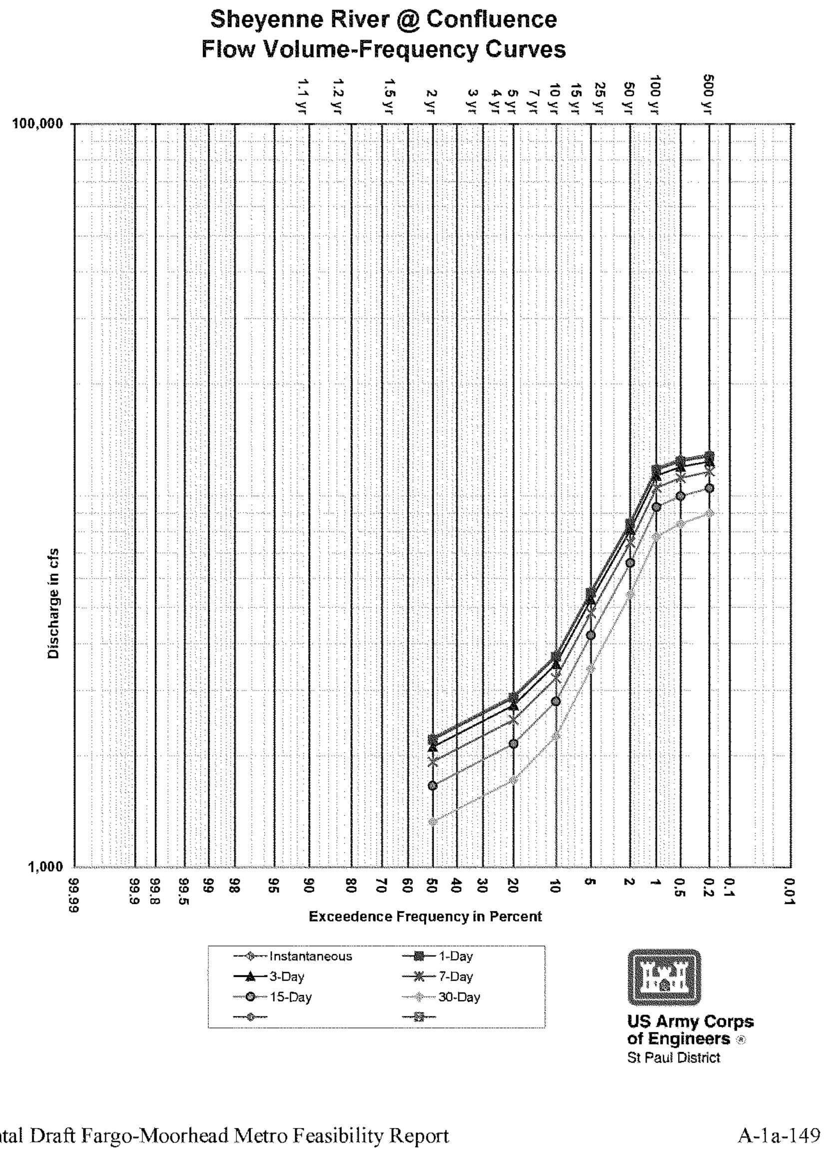
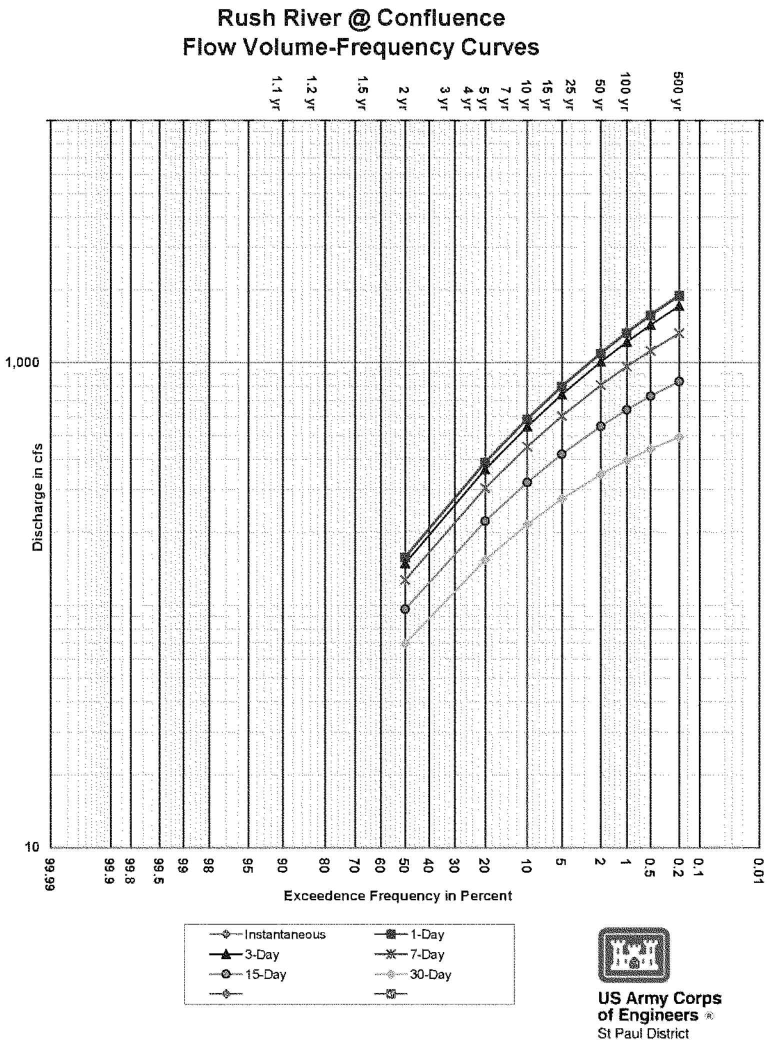


Figure 79- Rush River @ Confluence Flow Volume-Frequency Curves



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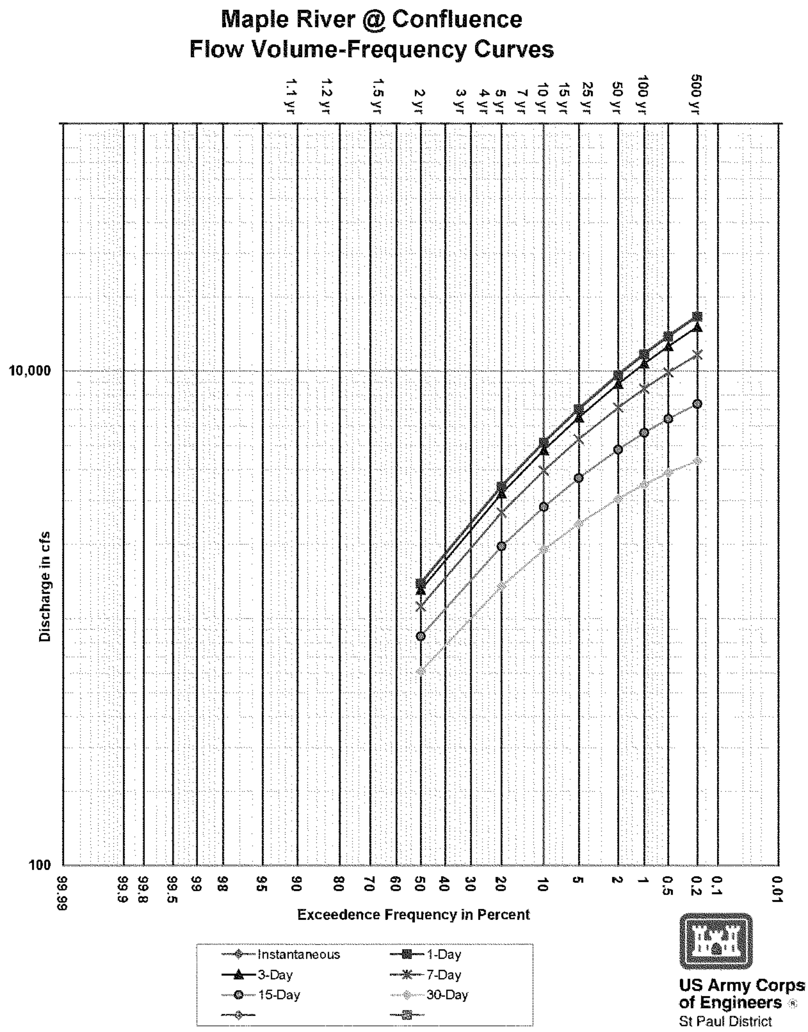


Figure 81- Balanced Hydrograph, Red River @ Wahpeton

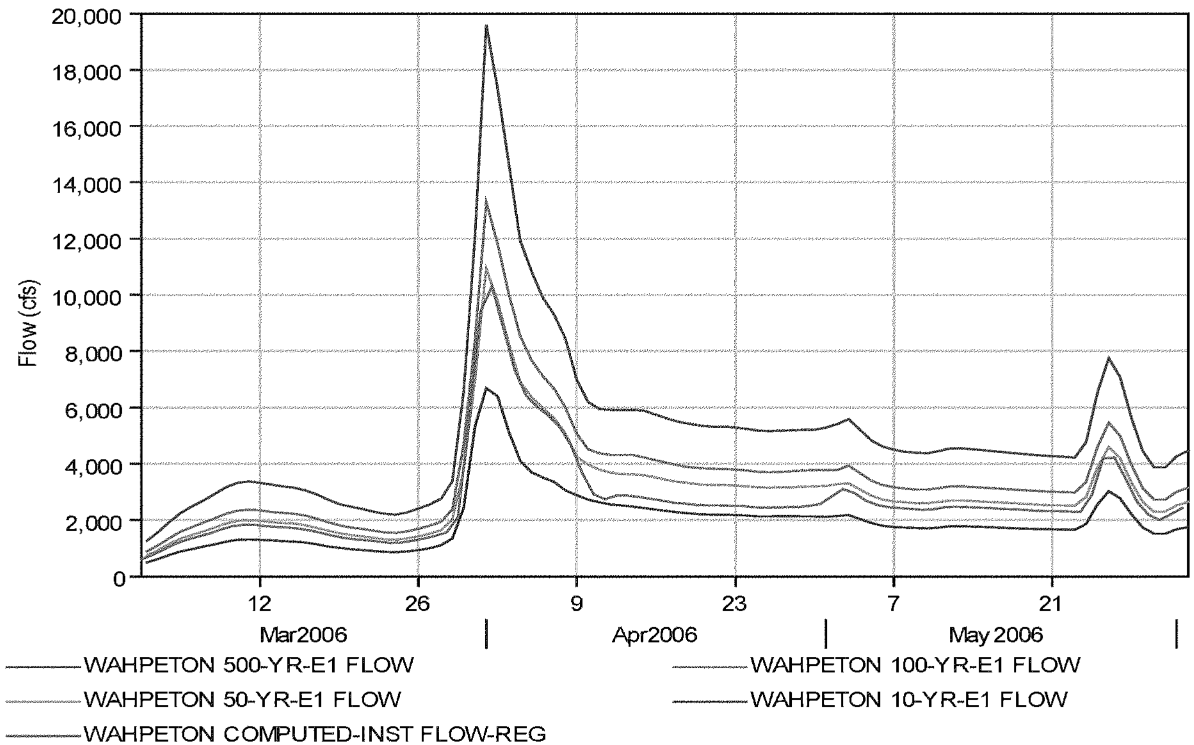


Figure 82-Balanced Hydrograph, Red River @ Hickson

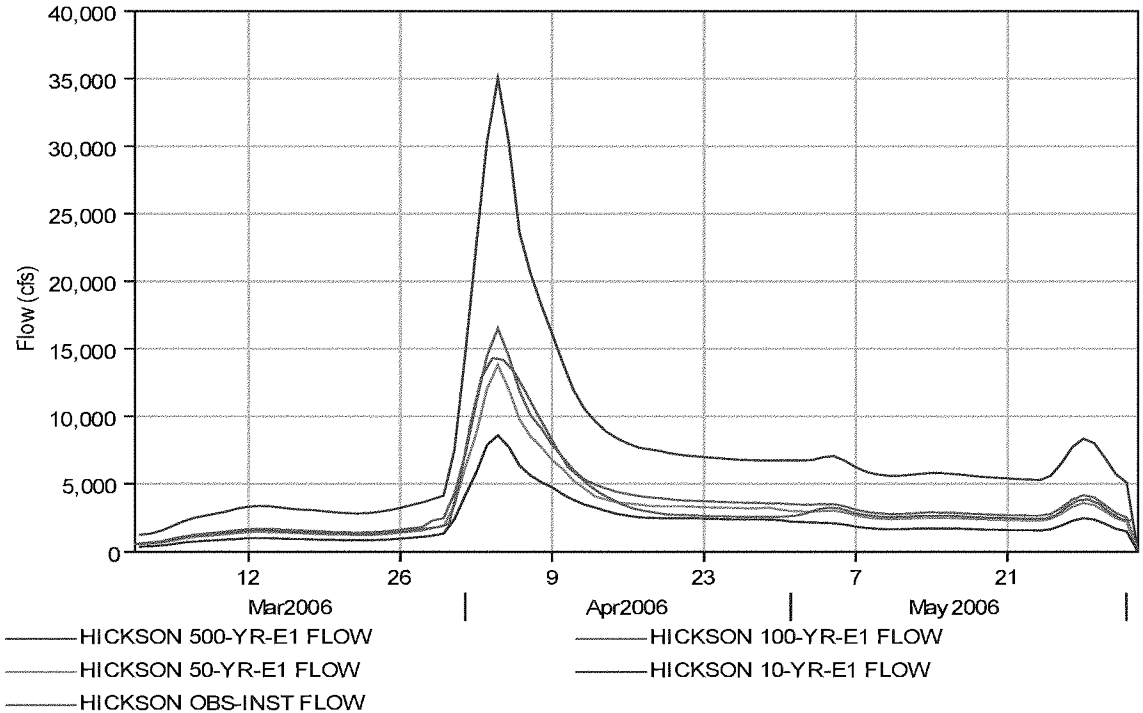
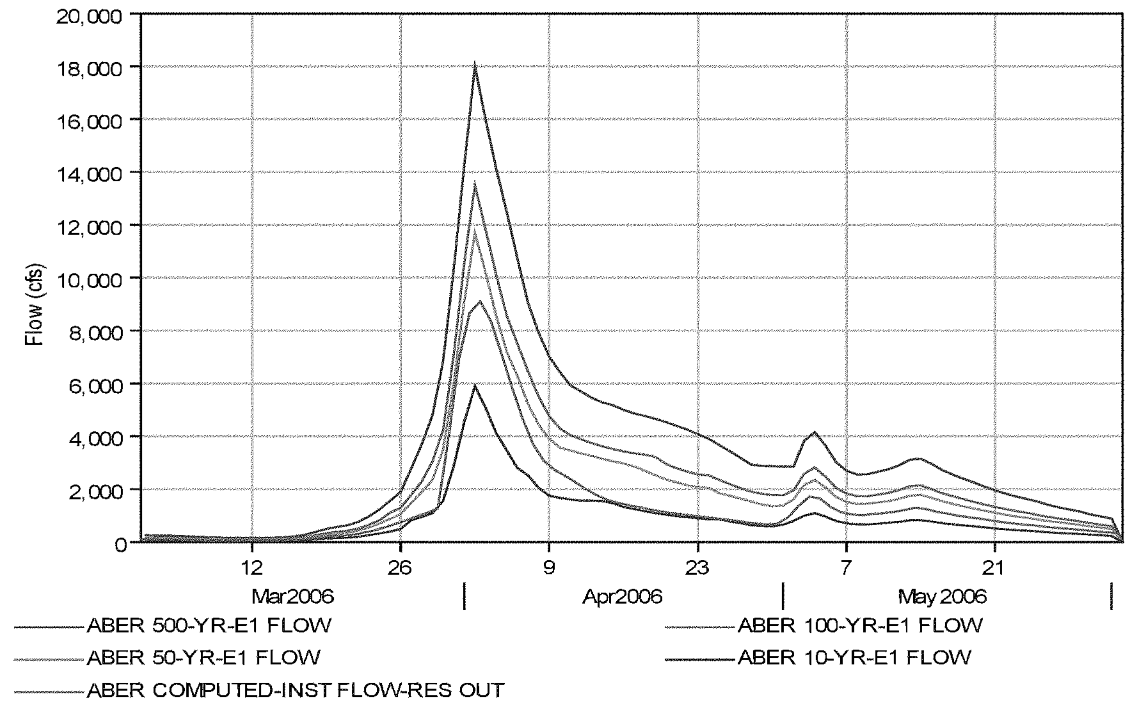


Figure 83- Balanced Hydrograph, Wild Rice River, ND at Confluence



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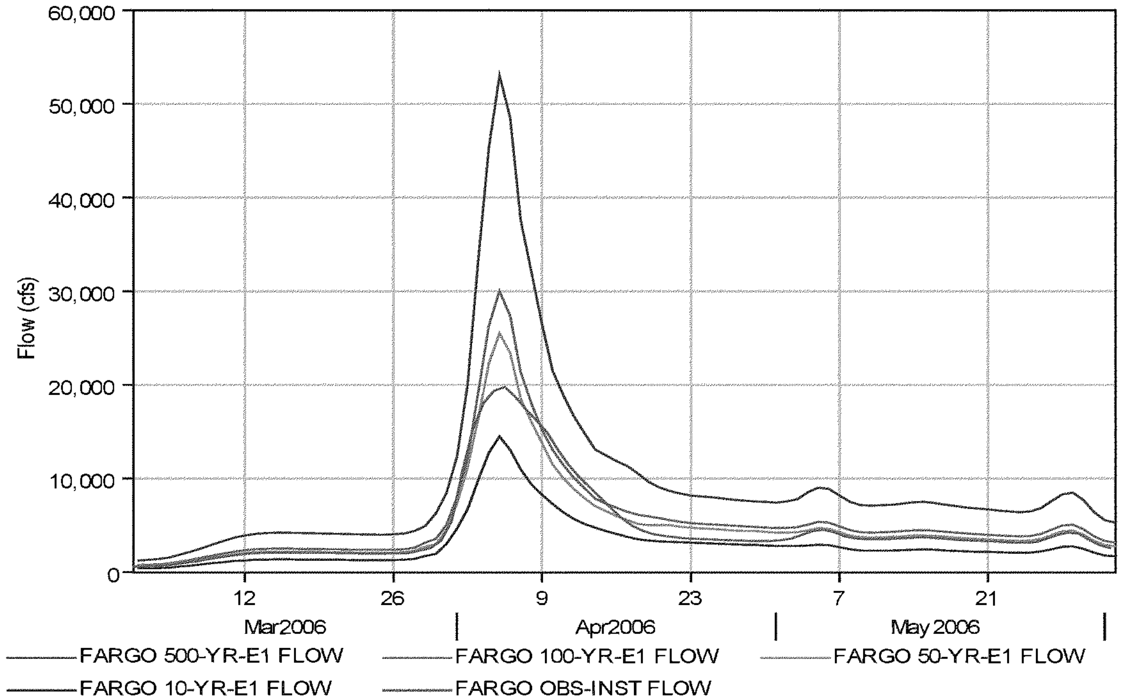


Figure 85- Balanced Hydrograph, Red River upstream of confluence with Sheyenne River

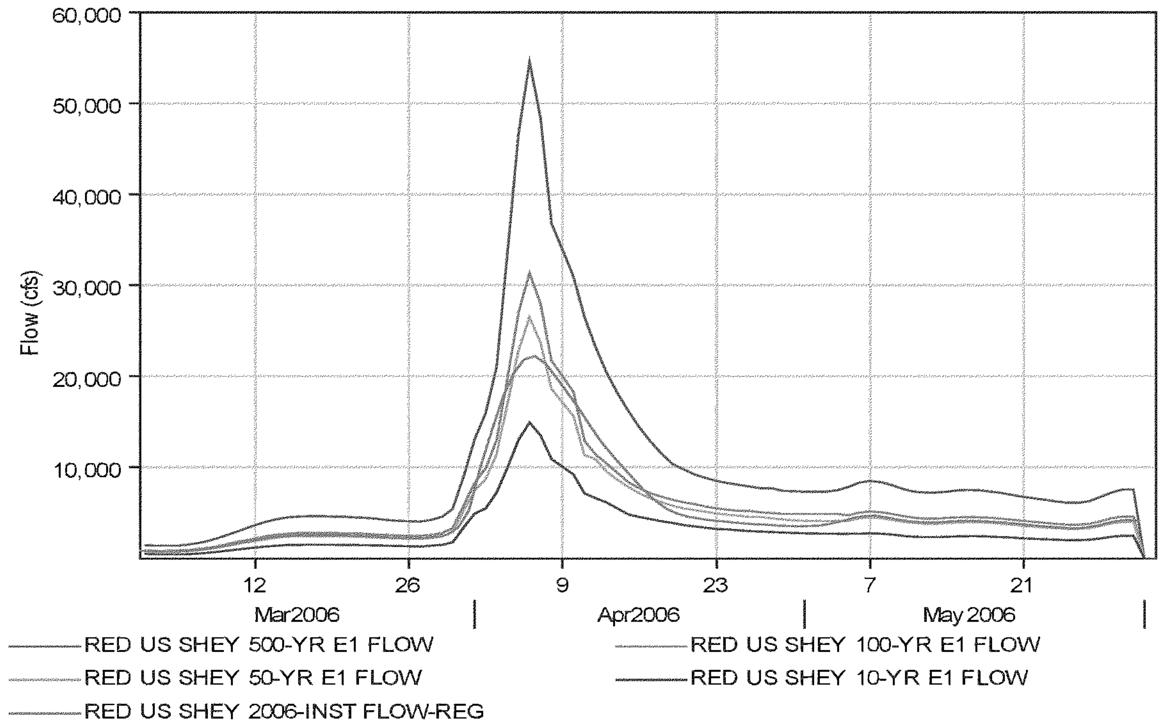
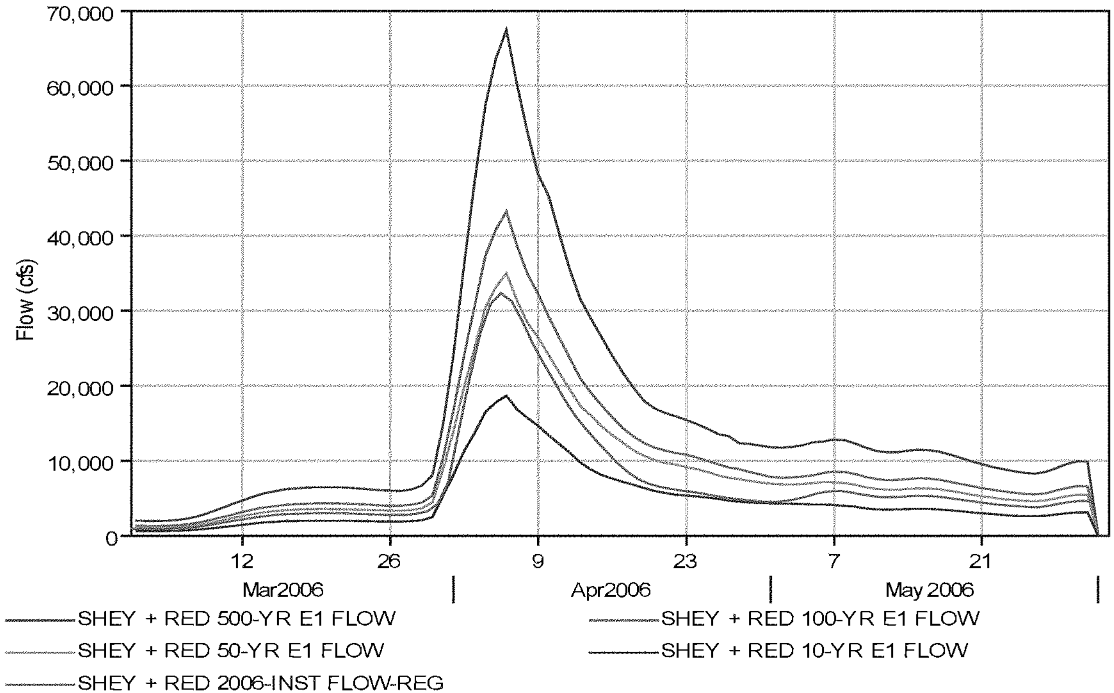


Figure 86-Balanced Hydrograph, Red River downstream of confluence with Sheyenne River



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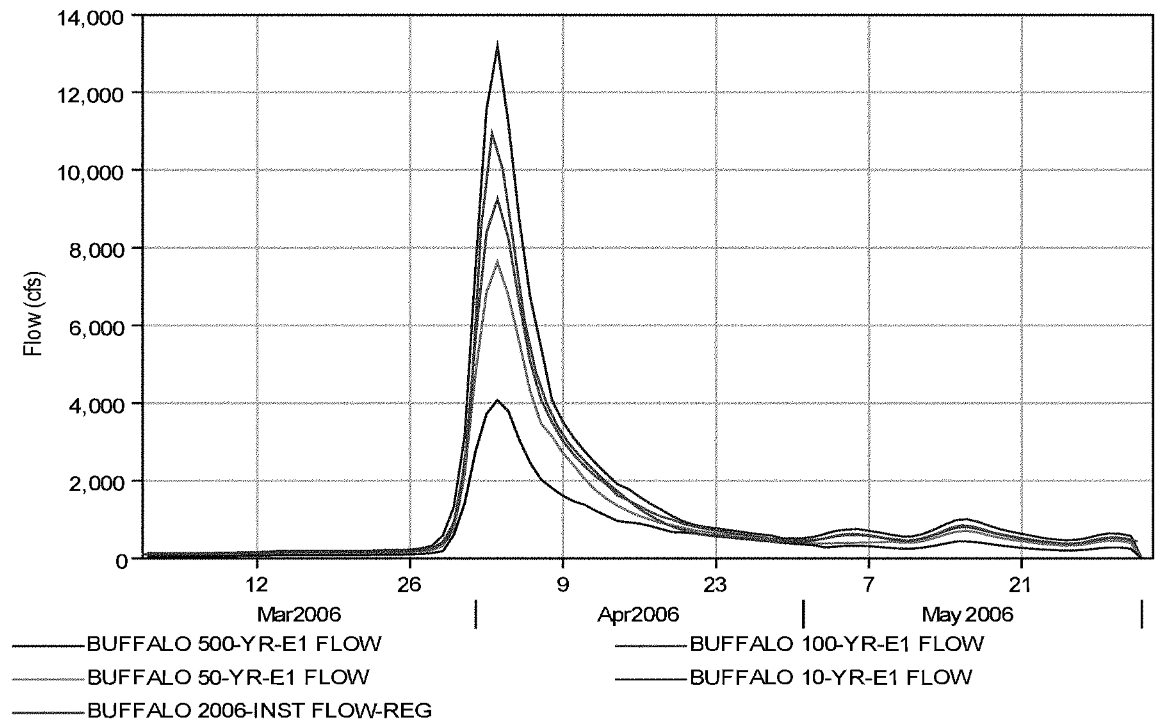

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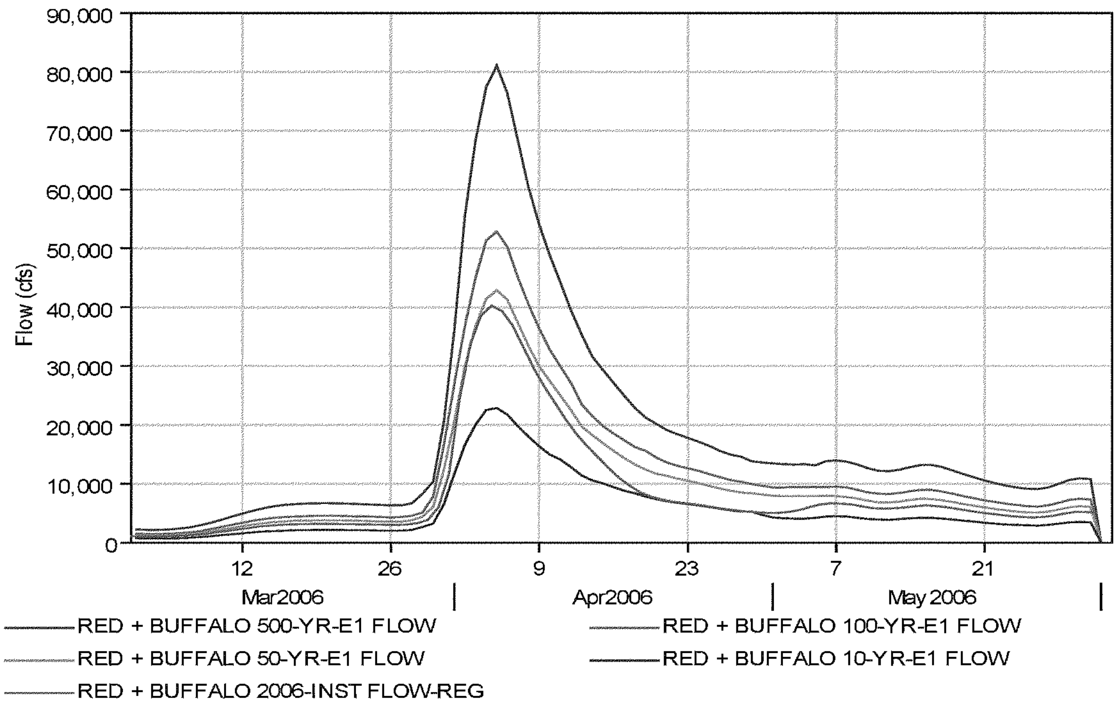
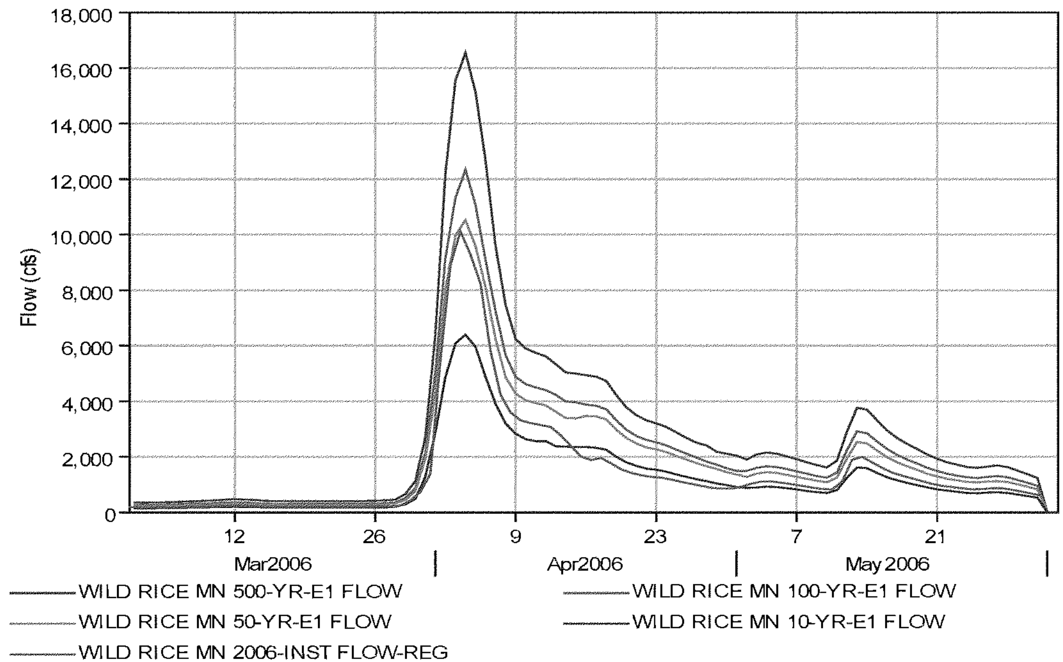


Figure 89- Balanced Hydrograph Wild Rice River



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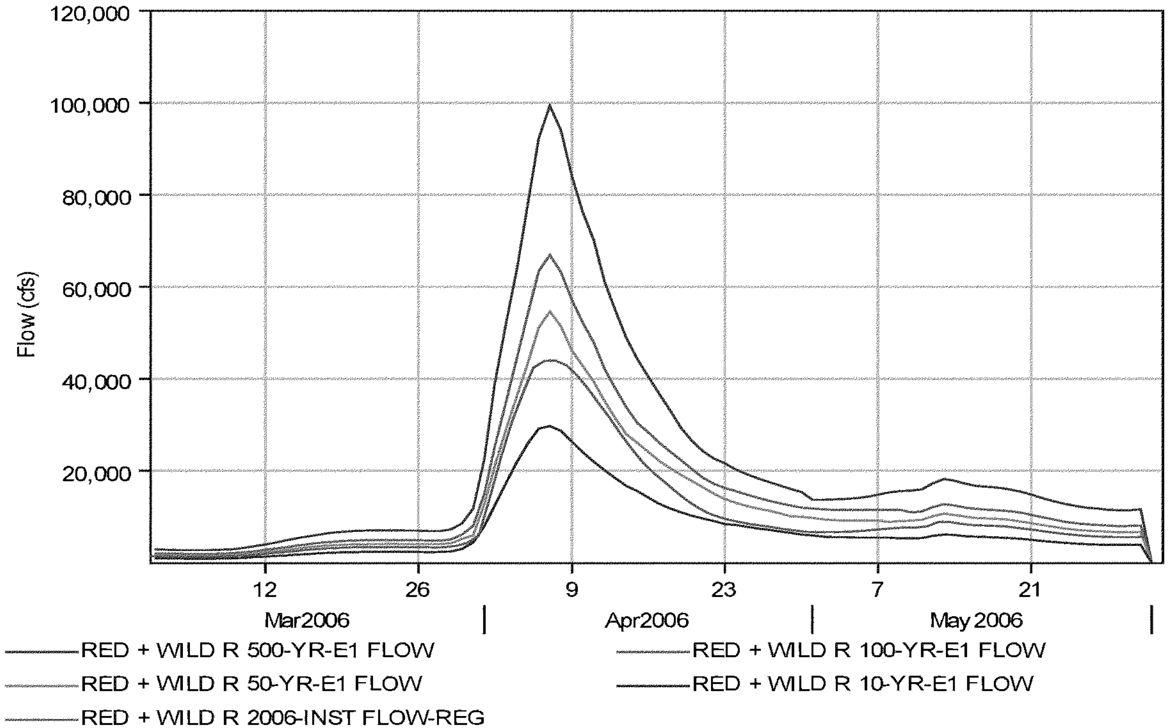

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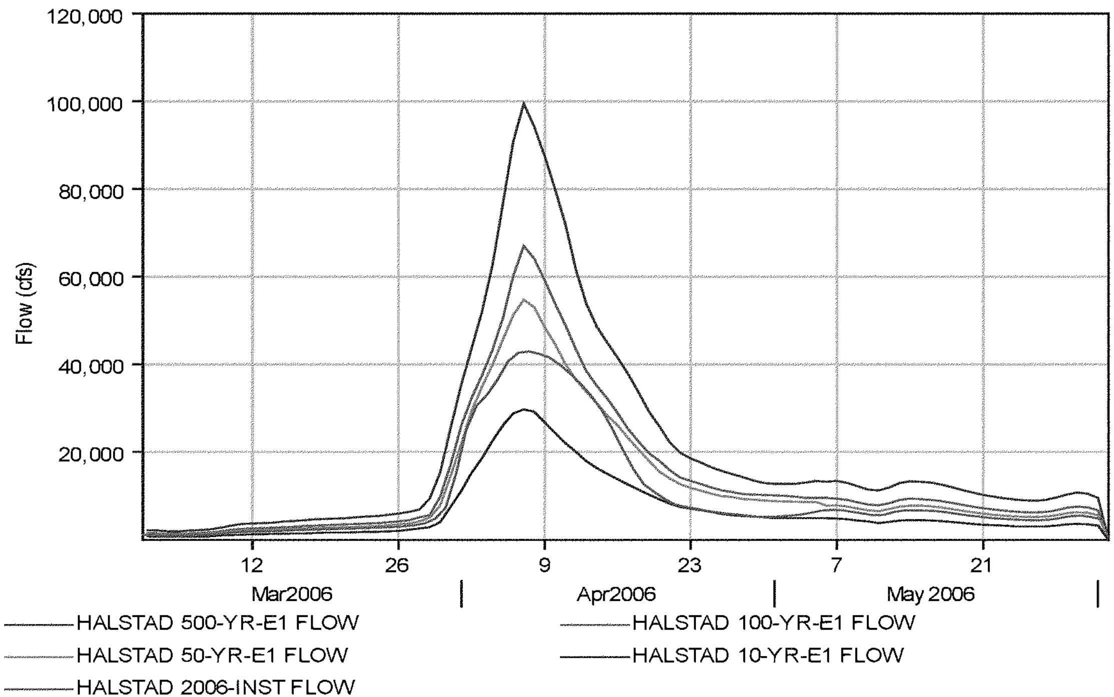

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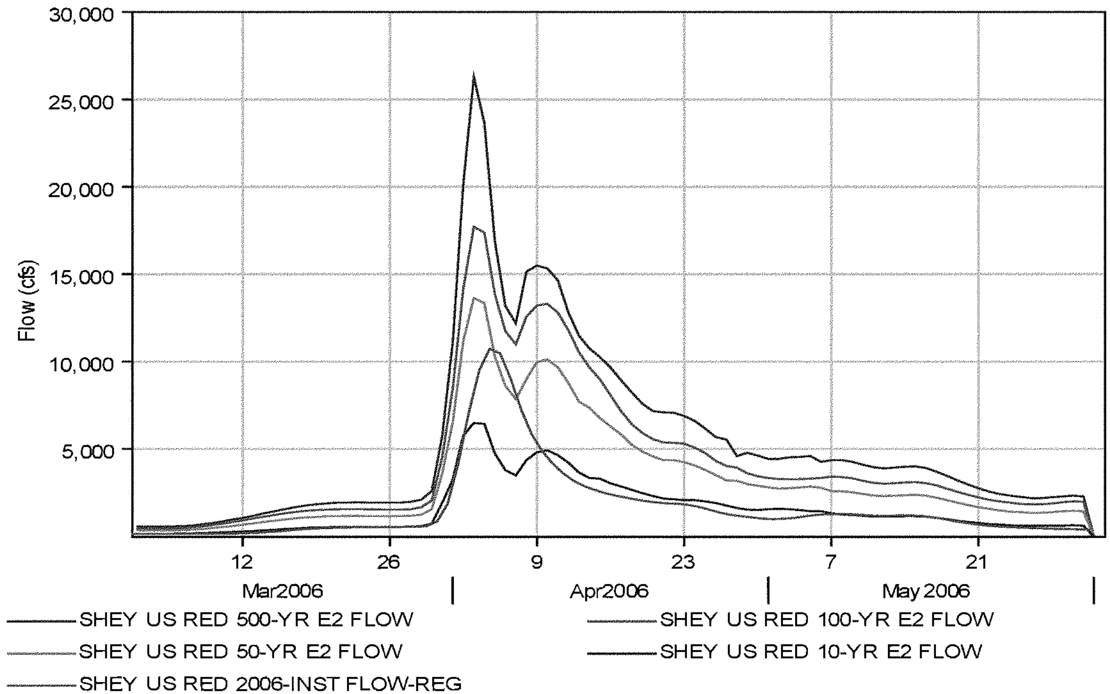
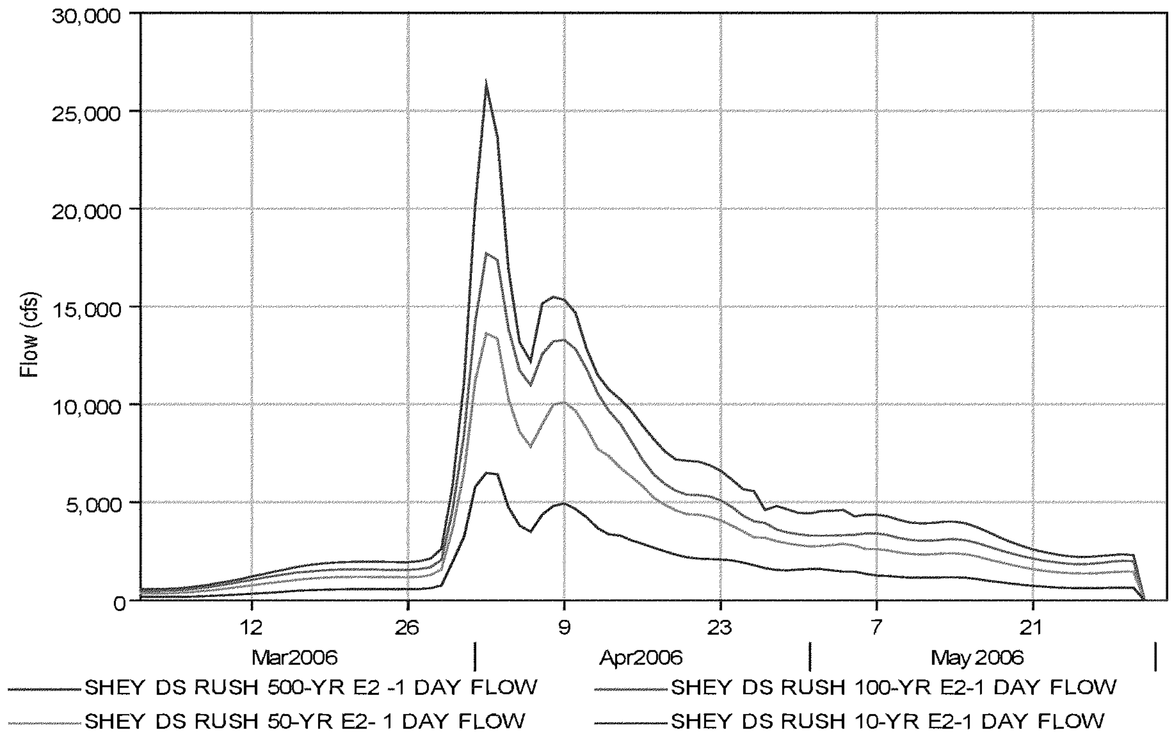


Figure 93-Balanced Hydrograph, Sheyenne River Downstream of its Confluence with the Rush River



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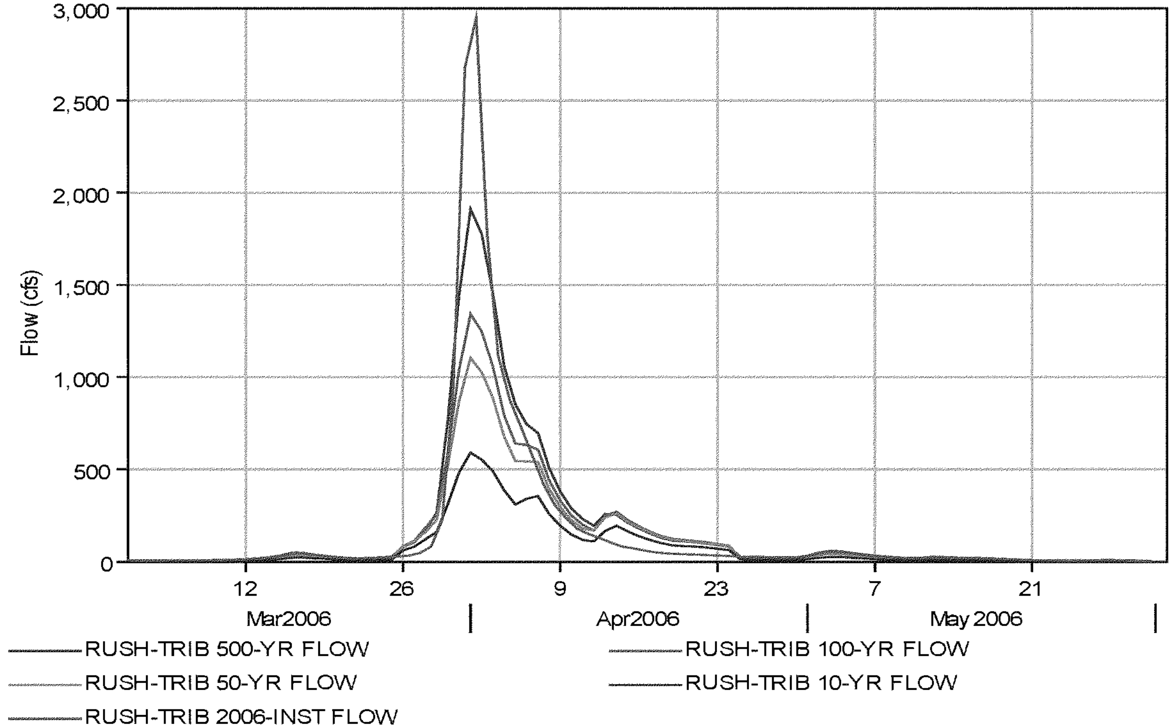


Figure 95- Balanced Hydrograph, Sheyenne River Upstream of its Confluence with the Rush River

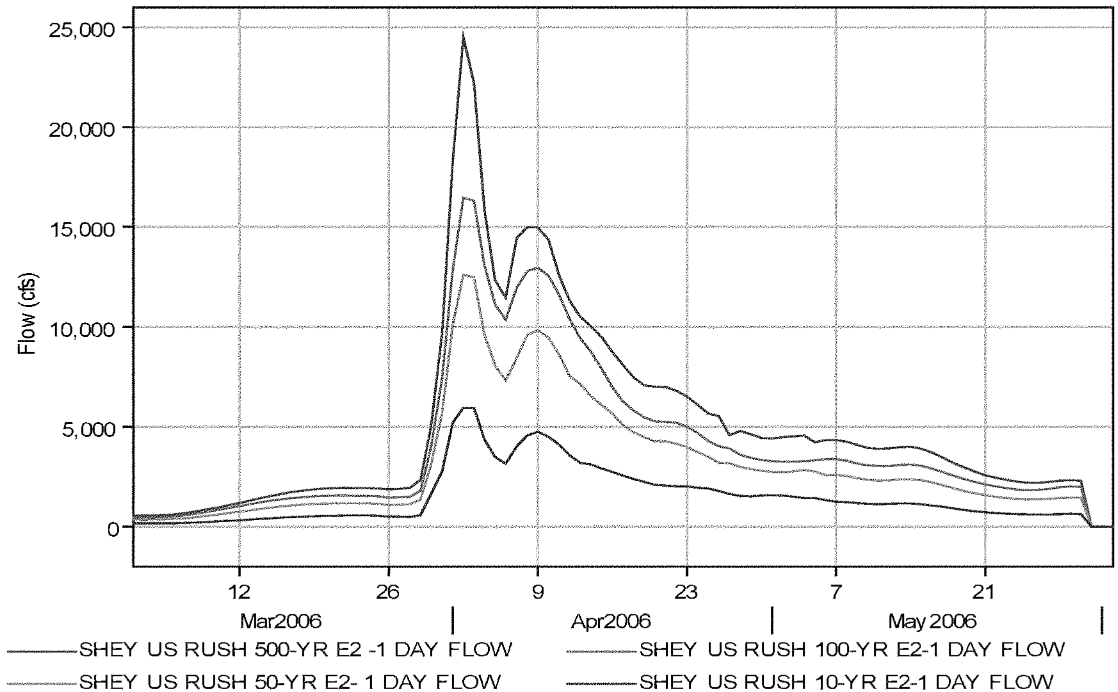


Figure 96- Balanced Hydrograph, Maple River at Confluence

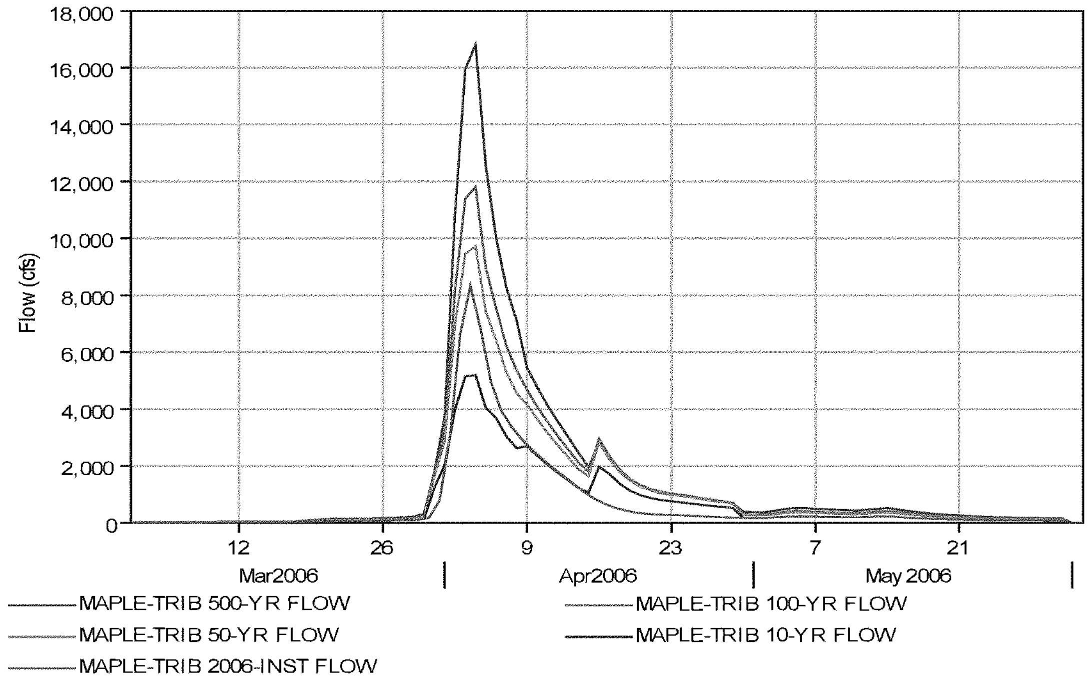


Figure 97- Balanced Hydrograph Sheyenne River Upstream of its Confluence with the Maple River

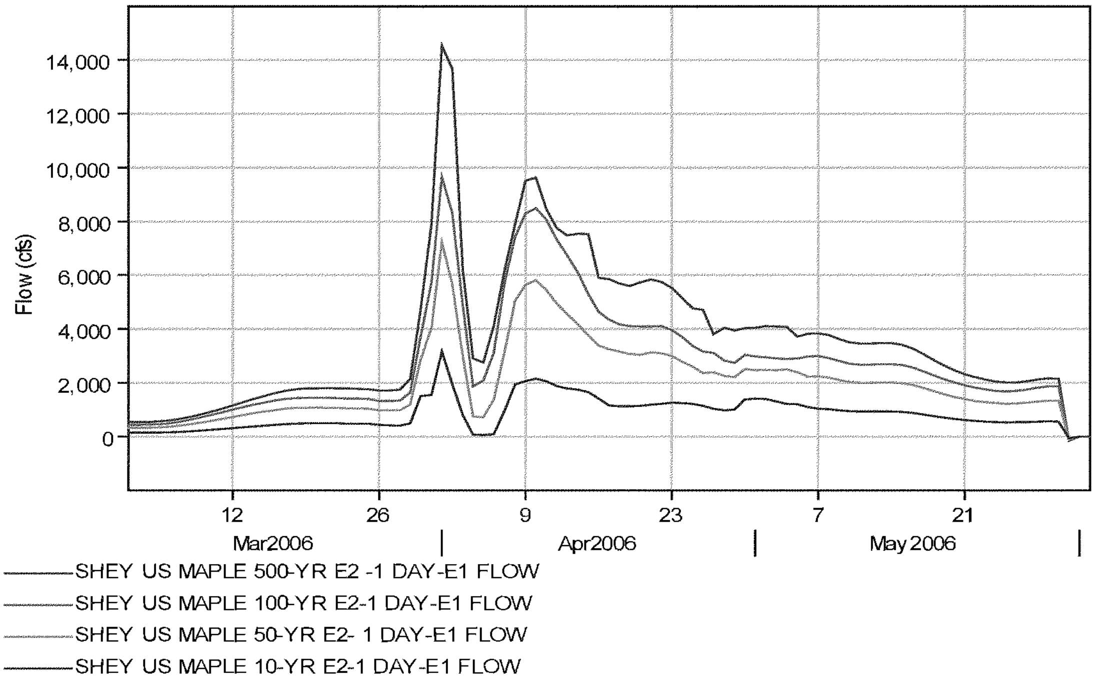
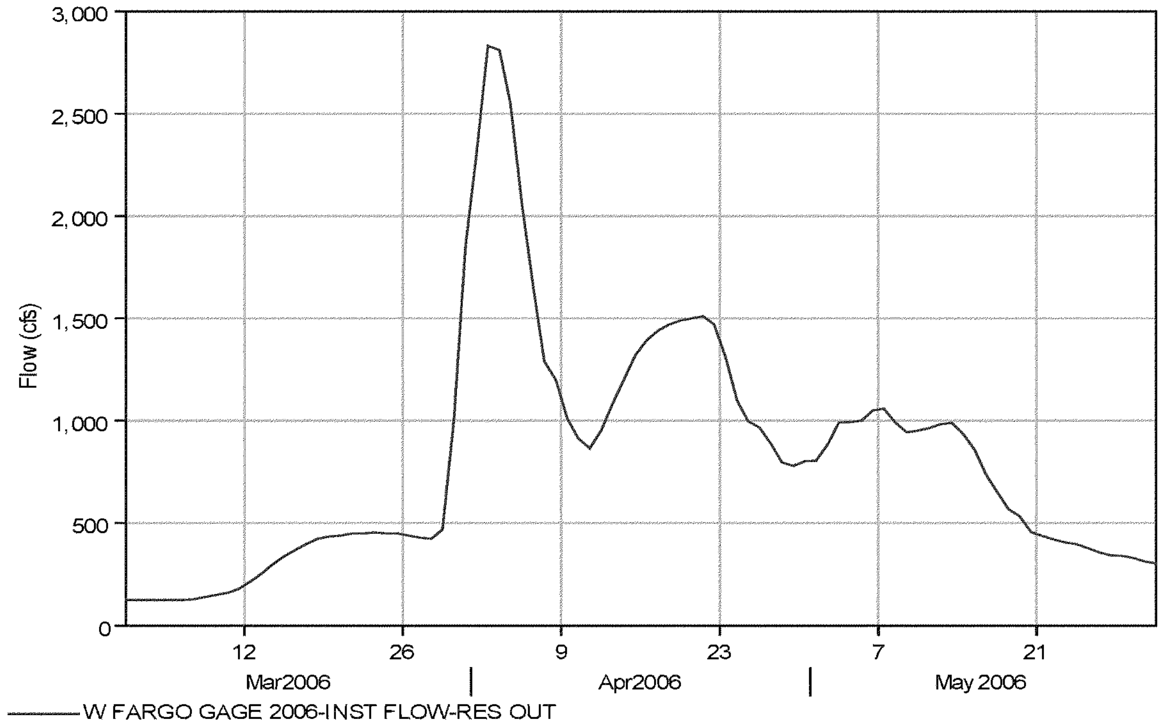


Figure 98- 2006 recorded event at the West Fargo gage



Appendix A-1b
Hydrology

Fargo-Moorhead Metropolitan Area Flood Risk Management

Supplemental Draft Feasibility Report and Environmental Impact Statement

April 2011

US Army Corps of Engineers®

Prepared by:
U.S. Army Corps of Engineers
St. Paul District
180 Fifth Street East, Suite 700
St. Paul, Minnesota 55101-1678

Expert opinion elicitation on impacts of increasing flood flows on the Fargo, ND-Moorhead, MN flood risk management project

October 19, 2009

US Army Corps of Engineers, St. Paul District

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Executive summary

The St. Paul District of the US Army Corps of Engineers (USACE) is studying the feasibility of a number of proposed flood risk reduction measures for the Fargo, ND-Moorhead, MN metropolitan area. These communities are exposed to flooding from the Red River of the North. Data show a trend of increasing magnitude and frequency of flooding in recent decades. A review of pertinent research suggests that this increase in flooding magnitude and frequency is consistent with projections of possible effects of climate change.

Given this, the Corps asked for an expert opinion elicitation (EOE) to serve two purposes: (1) to provide general guidance on how to account for climate change in the hydrologic and hydraulic analyses that support the Fargo-Moorhead feasibility study, and (2) to identify specific actions, if any, that should be taken to account for future probability and uncertainty in flood flows in the quantification of flood risk in the project area.

The topic of climate change was emphasized in the first question posed to the EOE expert panel: "Is it likely that climate change will have a significant impact on the flood flow frequency curve during the life of the proposed flood risk reduction project for Fargo, ND-Moorhead, MN?"

Following the first question, the experts and observers discussed the meaning of the phrase "climate change," particularly in the context of the Fargo-Moorhead flood risk reduction project. There was consensus among the experts that the recent data show a clear trend toward greater magnitudes and frequency of flooding in the Fargo-Moorhead area. It was also generally agreed among the experts and observers that current evidence is insufficient to determine whether or not anthropogenic greenhouse gases are contributing to the trend. However, the experts agreed that it was not necessary to determine the cause of the trend in order to address the Corps' second objective for the EOE (determining how to account for increased uncertainty).

In responding to the subsequent questions posed during the EOE meeting, the experts rather quickly moved away from a discussion of climate change, per se, and focused instead on the apparent lack of stationarity in the flood flow frequency and magnitude data over the period of record (the last 110 years or so).

Taken together, points made during the group discussions and the experts' written responses suggest that the following steps should be taken to adjust the flood frequency curve used in the hydrologic analysis supporting the Fargo-Moorhead feasibility study:

1. Develop, and use as the basis for the frequency analysis, an unregulated time series. Prior to the addition of significant regulation in the system, the series will be the recorded flows. After regulation was added, the recorded flows must be adjusted to "remove" the effects of regulation in the system. This can be done with the reservoir and channel routing models that the District has available.
2. Develop and use a transform function to convert the derived unregulated frequency function to the regulated frequency function that is required for the risk analysis. This transform function can be developed by simulating system behavior without and with regulation for floods from the period of record (POR). As the historical floods may fail to cover adequately the

range of flows needed to define the frequency curve well, historical events can be scaled to simulate larger floods. This is consistent with guidance in EM 1110-2-1415.

3. Analyze the unregulated flow series, and divide the current POR into two portions. Suggestions for identifying the "break" between the wet period and the dry period included:
   - Using qualitative judgment, e.g., define the dry period as 1901-1941 and the wet period as 1942-2009; or define the dry period as 1901-1960 and the wet period as 1961-2009.
   - Use statistical tests for homogeneity to determine where to divide the POR. The expert panel did not agree on the statistical tests, but did note work by Villarini, et al.
4. Fit a log Pearson III distribution separately to the dry components of the split record and the wet component, following generally the guidance in *Bulletin 17B*. Some members of the panel suggested using the total record to estimate the skew coefficient to be used for both components. Others suggested determining the skew coefficients for each portion of the POR separately. If the skew coefficients are close, an appropriately rounded average of the two could be used.
5. Combine the "wet" and "dry" curves, and weight the probabilities for continued wet conditions versus a reemergence of dry conditions. Two schemes emerged from the majority of the experts' responses:
   - Transition from wet to dry over time. For example, begin with p(wet)=1 and p(dry)=0 in year 1 of the project, moving to p(wet)=0.5 and p(dry)=0.5 in year 50, or move p(wet) from 1 to 0 over the life of the project.
   - Do not change the probabilities over time, e.g., p(wet)=0.8 and p(dry)=0.2 over the entire 50-year project life.
6. Account for greater uncertainty. One suggestion was to use an equivalent POR in the Corps Hydrologic Engineering Center's Flood Damage Analysis (HEC-FDA) equal to the number of years of the smaller portion of the POR (either the wet portion or the dry portion).

Overview of Fargo-Moorhead EOE

The Fargo-Moorhead EOE, which was held on September 28-29, 2009, in St. Paul, MN, was planned and implemented according to these three guidance documents:

- *Technical guide for use of expert opinion elicitation for U.S. Army Corps of Engineers risk assessments*, USACE Dam Safety Risk Management Center (2009).
- *A practical guide on conducting expert-opinion elicitation of probabilities and consequences for Corps facilities*, IWR Report 01-R-01 (2001).
- *Methods for expert-opinion elicitation of probabilities and consequences for Corps facilities*, IWR Report 00-R-10 (2000).

The *Technical guide* requires a Level II EOE when the specific information sought is not available from historical records, prediction methods, or literature review. Therefore, the Fargo-Moorhead EOE was a Level II EOE.

Why this EOE was needed

The Fargo, ND-Moorhead, MN metropolitan area has a relatively high risk of flooding from the Red River of the North and relies on emergency responses to ensure safety of the community. Given the high flood risk, the St. Paul District of the US Army Corps of Engineers is completing a feasibility study of alternative measures to reduce flood risk in the Fargo-Moorhead area.

The highest river stages usually occur as a result of spring snowmelt, but summer rainfall events have also caused significant flood damages. In fact, the Red River of the North has exceeded the National Weather Service flood stage of 17 feet in 50 of the past 106 years, and every year from 1993 through 2009.

A review of Red River flow data verifies the increase in flood magnitude and frequency in the relatively recent decades of the period of record (1901-2009). A time series of natural annual maximum mean daily flow for the Red River at Fargo is shown in Figure 1 (Source: David Ford Consulting Engineers, Inc., using USACE data). As can be seen, both the magnitude and variability of the flows have increased since the beginning of record. A review of pertinent research suggests that this increase in flooding magnitude and frequency is consistent with projections of possible effects of climate change.

The Fargo-Moorhead feasibility study follows Corps planning study guidelines, which require that "[r]isk-based analysis... be used to compare plans in terms of the likelihood and variability of their physical performance, economic success and residual risks" (ER 1105-2-100). The annual maximum discharge-probability function (also known as the flood flow frequency curve) at the location of interest is a key input to the risk analysis. For the Fargo-Moorhead project, the Red River frequency was developed following Corps guidelines in EM 1110-2-1415, *Hydrologic frequency analysis,* and EM 1110-2-1417, *Flood-runoff analysis*.

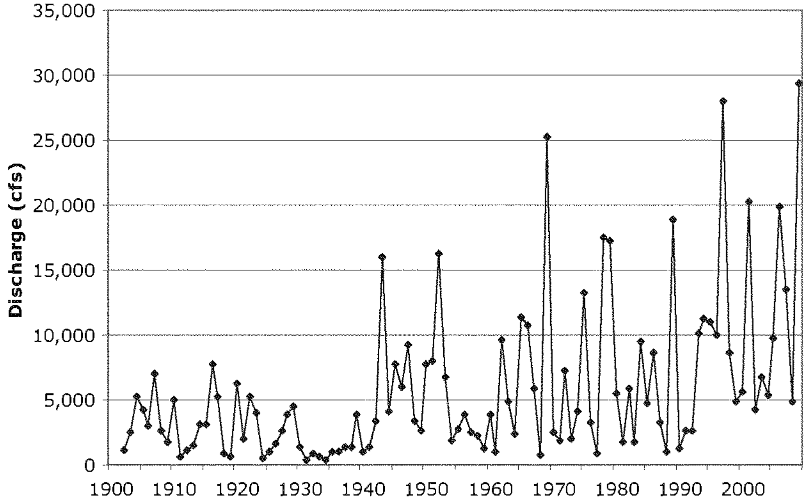

Figure 1. Natural annual maximum mean daily flow - Red River at Fargo

The observed trend in flood flow frequency and magnitude raises the question of whether the current proposed curve accurately represents future conditions for purposes of the feasibility study's risk analysis.

Therefore, to ensure a reliable and robust plan and project design, the Corps Fargo-Moorhead project delivery team (PDT) organized an EOE. The Fargo-Moorhead EOE was held to provide the PDT with specific actions that should be taken, if any, to account for future flood flow magnitude and frequency uncertainty in the quantification of flood risk in the project area.

Fargo-Moorhead EOE participants

Participants in the EOE included six experts chosen by the St. Paul District to serve on the expert panel, five invited observers with specialized knowledge, and staff of the USACE St. Paul District. David Ford, PhD, PE, D.WRE, served as the technical integrator and facilitator (TIF). (David Ford is president of David Ford Consulting Engineers, Inc., the consulting firm selected to organize, prepare for, and facilitate the EOE, and to aggregate and present the EOE results.)

The experts (those who submitted their opinions in writing) are identified in Table 1.

Table 1. Fargo-Moorhead EOE experts

Expert	Affiliation
Michael Deering, PE, D.WRE	Senior Hydraulic Engineer, Water Resource System Division, USACE Hydrologic Engineering Center
Scott Dummer	Hydrologist-in-Charge, National Weather Service North Central River Forecast Center, Chanhassen, MN
Robert Hirsch, PhD	Research Hydrologist, US Geological Survey (USGS) National Research Program
Rolf Olsen, PhD	Water Resources Systems Engineer, USACE Institute for Water Resources
David Raff, PhD, PE	Technical Specialist, Flood Hydrology and Emergency Management Group, Technical Services Center, US Bureau of Reclamation (USBR)
Aldo (Skip) Vecchia, PhD	Research Statistician, USGS

Fargo-Moorhead EOE observers are identified in Table 2.

Table 2. Fargo-Moorhead EOE observers

Observer	Affiliation
Adnan Akyuz, PhD	North Dakota State Climatologist
Ronald Beyer, PE	Hydraulic Engineer, Omaha District, USACE
Greg Hiemenz	Environmental Specialist, Dakotas Area Office, USBR Great Plains Region
David Moser, PhD	Chief Economist, USACE
Richard Pemble, PhD	Retired Professor of Biology, Minnesota State University, Moorhead
Gregg Wiche	Water Science Center Director, USGS North Dakota

Other individuals present for all or part of the proceedings included:

- Michael Knoff, PE, Chief, Hydraulics and Hydrology Branch, St. Paul District, USACE
- Patrick Foley, PE, Chief, Hydraulics Section, St. Paul District, USACE
- Dan Reinartz, PE, Senior Hydraulic Engineer in the Hydraulics and Hydrology Branch, Water Control Section, St. Paul District, USACE
- Mike Lesher, Senior Hydraulic Engineer in the Hydraulics and Hydrology Branch, Hydraulics Section, St. Paul District, USACE
- Craig Evans, Senior Planner, Project Management Branch, St. Paul District, USACE
- Chanel Kass, Civil Engineer, St. Paul District, USACE
- Rhonda Robins, Water Resources Planner, David Ford Consulting Engineers, Inc.

While each of the experts is an employee of an agency involved in flood flow frequency analysis, the opinions they offered were understood to be their personal opinions, and not necessarily the positions of any particular agency. Accordingly, throughout this memo, the opinions and ideas of the experts are reported without attribution. Similarly, comments by the invited observers are reported without attribution.

EOE meeting summary

To prepare for the EOE, expert panel members and observers were sent a read-ahead package following recommendations in the *Technical guide*.

The EOE began with a description of the EOE process and a review of the goals to be accomplished. Then, Ford asked that the experts be mindful of these assumptions:

- The Red River of the North presents a unique hydrologic and hydraulic record, and therefore the results of this EOE do not necessarily set precedent for other regions of the country.
- The time scale of a Corps project is a matter of decades: the life of a project is considered to be 50 years, and the economic analysis often focuses on the first 20-30 years, as this has the greatest impact on the discounted benefits and costs.
- The recommendations that result from this EOE must be implemented within the time, budget, and resource constraints of this project.

Ford also presented an overview of the Corps risk and uncertainty analysis procedures and requirements.

St. Paul District staff presented information about the Corps' flood risk reduction alternatives for the Fargo-Moorhead region, hydrologic and hydraulic analyses related to the Red River of the North and its tributaries, and the apparent climate trend toward an increase in magnitude and frequency of flood events in this region.

After the background information was presented, Ford posed the first question to the experts. The experts wrote their responses on carbonless copy paper. They submitted one copy of each answer to the TIF, and kept the other copy so they could refer to it during the discussion period that followed.

The experts' responses to the first question were shared with the participants and a group discussion followed. Each expert was given an opportunity to explain his answer, and the observers and others were encouraged to ask questions and contribute pertinent information.

Following the group discussion, the experts were asked to respond to the same question again in light of the discussion. As before, they wrote their answers on carbonless copy paper. Each expert kept one copy for future reference and submitted the other copy to the TIF.

When all the experts had turned in their final responses to the first question, the question was closed, and the TIF proceeded with the next question. For the Fargo-Moorhead EOE, a total of four questions were posed.

Experts' opinions

Each question, a summary of the experts' preliminary responses, and a summary of the experts' final responses is provided here.

Question 1

Preliminary: Is it likely that climate change will have a significant impact on the flood flow frequency curve during the life of the proposed flood risk reduction project for Fargo, ND-Moorhead, MN?

The experts were evenly divided in their responses to Question 1: three experts gave a qualified "yes," and three experts gave a qualified "no." Several responses questioned whether the term "climate change" meant an anthropogenic increase in greenhouse gases leading to global warming. Several stated that climate change, which they defined as taking place over a much longer time frame, would not have an effect on flood frequencies over the time period of analysis (20-30 years). All responses acknowledged that natural decadal-scale variability was present in the data. Many responses commented that this variability increases the uncertainty about flood frequency over the next 20-30 years. In sum, the answers seemed to say this: if climate change means global warming over thousands of years, no, it will not impact flood frequency over the life of this project. If climate change means natural variability over a time scale of decades, yes, it probably will impact flood frequency over the life of this project, but we do not know how to predict the impact very well.

During the discussion that followed each expert's preliminary responses to Question 1, there was much talk of what "climate change" means in the context of the Fargo-Moorhead project. There was consensus among the experts that the data show a clear trend toward greater magnitudes and frequency of flooding in the Fargo-Moorhead area. It was also generally agreed among the experts and observers that there is currently insufficient evidence to determine whether or not anthropogenic greenhouse gases are contributing to the trend. Finally, the experts agreed that it was not necessary to determine the cause of the trend in order to examine the question at hand.

Final:

(a) Has historical climate change/variability been accounted for in an appropriate manner in the proposed frequency analysis?

(b) If climate has been addressed appropriately to date, do we need to consider climate change in the flow frequency curve?

To part (a), there were five "no" votes and one "yes" vote. Most responses said that the current analysis (reported in the Corps' feasibility study) does not acknowledge the lack of homogeneity in the flood frequency and flood magnitude data.

To part (b), there were five "yes" votes and one "no" vote. Most responses agreed that project planners need to account for the apparent shifts in and uncertainty in future precipitation and flood flow frequency.

Question 2

Preliminary: How will the frequency curve change?

In answering this question, the experts began to focus on the idea that the POR shows two states, a relatively dry period early in the 20th century and a relatively wet period later in the 20th century. Some experts stated that it was likely the current wet period would persist for some period of time in the future, while others stated that there is no way to know what will happen in the future. A consensus emerged about the need to account for greater uncertainty, whether or not the curve itself is changed.

Final: How will the flow frequency curve for the full range change?

The experts' final responses emphasized these concepts:

- The POR used in the feasibility study's hydrologic analysis, which spans 1901-2009, shows two distinct states: a relatively dry period in the early 20th century and a relatively wet period in the latter decades of the POR.
- To estimate flood risk over the next 50 years, which is what the Corps must do, a prediction must be made about whether and for how long the current wet period will continue.
- Greater uncertainty must be accounted for, whether or not the flood flow frequency curve itself is changed.

Question 3

Preliminary: What are the practicable alternatives for accounting for the impact of the change?

The experts' responses showed that they were thinking of a two-state or mixed-population system, with the POR divided at some point in the mid-20th century between the earlier relatively dry period and the more recent relatively wet period. All the experts' responses included some variation on the theme of dividing the POR into a wet portion and a dry portion. Two experts suggested using only the more recent wet portion of the POR. Two experts suggested developing a wet period curve and a dry period curve, and re-combining them into a single curve using some kind of transition function based on the probabilities of wet and dry conditions occurring in the future. Another suggested using the current curve in the early years of the project, and then "jumping" to a "climate change" curve at some future year of the analysis.

Final (same as initial): What are the practicable alternatives for accounting for the impact of the change?

The two-state or mixed-population approach gained further traction in the experts' final answers to Question 3. They focused on two issues in particular:

- Assuming the POR is divided into two portions, should both portions of the POR be used or just the more recent one?
- If both portions are used and then recombined into a single curve, what should the relative weights of the wet period and the dry period be?

Representative suggestions included:

- Using the two separate portions of the POR, and recombining them using a weighting scheme to transition from wet to dry over time. The relative weights would depend on how likely it is the wet period will persist versus how likely it is that a dry period will occur in the future years of the project life.

- Using only the most recent portion of the POR as way to account for greater uncertainty, with the shorter POR serving to increase the upper confidence curve.
- Doing a scenario analysis for three distributions: the entire POR, a mixed distribution, and a wet period distribution, and keeping them separate for the economic analysis.
- Running HEC-FDA with the current frequency curve, and then running it with a wet period frequency curve. This suggestion included applying year-to-year weightings, and determining a combined expected annual damage (EAD) outside of HEC-FDA.

Question 4

Preliminary: Of the alternatives available, which is best for this particular application, given the limitations imposed by the urgent need to reduce risk in Fargo-Moorhead?

The responses to Question 4 acknowledged the time constraints present for the Fargo-Moorhead feasibility study. Further, the experts' responses to Question 4 did not differ substantively from their final responses to Question 3, except that several of the experts added more specificity and detail to their earlier answers. The following are paraphrased from the experts' written answers:

- Make separate HEC-FDA runs using the current frequency curve and a wet period frequency curve. Prepare a spreadsheet that combines weighted EADs incrementally to include combined uncertainties.
- Treat the entire POR as a mixed population, and divide it into a wet period and a dry period using statistical analyses for homogeneity. Develop two separate flow functions, weight them appropriately, then combine them. Weight the probability of continued wet conditions at 0.8, and dry conditions at 0.2.
- Use two frequency curves, one for the period 1960-2009, and the other for the entire POR. Combine the two curves into one curve for each future year using specified probabilities that transition gradually from p=1 for the wet curve and p=0 for the dry curve at the beginning of the analysis period to p=0 for the dry curve and p=1 for the wet curve at the end of the analysis period.
- Ideal approaches to weighting include exploring the use of a Markov chain, using the 600-year rain record, or probability/percentage of dry periods occurring in the next 50 years.
- Use the current curve in the early years of the project, and then "jump" to a "climate change" curve at some future year of the analysis.
- Quick subjective probabilities would be wet p=0.75 and dry p=0.25.
- The final result should be weighted in favor of a continued wet period, with allowance for the occurrence of a dry period not to exceed p=0.5.

- Two frequency curves should be considered from the observed record. The dividing line in the POR can be defined subjectively, or if time allows, using statistical tests for homogeneity.
- Take a mixed population approach as follows:
  - Divide the POR into two portions: 1942-2009 and 1902-1941, based on a paper by Villarini, Serinaldi, Smith, and Krajewski in *Water Resources Research*, Vol. 45, WO8417, 2009. These authors did a change point analysis for change in the mean based on the Pettitt test, and the Fargo record shows a significant step change at 1942.
  - Do LPIII analysis on each period, but to estimate skew, take all the data values (the log discharges) and subtract the group mean, divide by the group standard deviation from the appropriate group and then compute a skewness on all 108 values.
  - Set a subjective estimate of the marginal probabilities of being in the wet (later) population at 0.8 and a probability of the dry (earlier) population at 0.2.
  - For sensitivity analysis, try setting the probability of the dry population at 0.37 (its proportion in the current data set) and also at zero (meaning no return to the dry state).

Final (same as initial): Of the alternatives available, which is best for this particular application, given the limitations imposed by the urgent need to reduce risk in Fargo-Moorhead?

The group discussions and experts' responses to Question 4 focused on these four related questions:

- How should the current POR be divided into two portions?
- How should the skew coefficient be determined for the two portions?
- How should the two separate curves be combined to arrive at a single curve?
- How should uncertainty be accounted for?

The experts suggested that the POR could be divided using qualitative judgment or statistical homogeneity tests. Several experts suggested that skew coefficients for the two portions of the POR should be calculated independently, and if close, the average of the two could be used.

Most of the experts favored some kind of weighting scheme for combining the wet curve and the dry curve, such as a function that transitions from the current wet period to a dry period in future years. For example, two experts suggested p(wet)=1 and p(dry)=0 in year 1 of the project, moving to p(wet)=0.5 and p(dry)=0.5 in year 50. Another expert had p(wet) moving from 1 to 0 over the life of the project. Alternatively, another expert suggested setting the relative weights as unchanging over time, with p(wet)=0.8 and p(dry)=0.2.

Most experts either suggested or implied that further investigation was needed to determine the best way to account for uncertainty in EAD and project performance. One expert suggested using the number of years in the shorter of the two portions (wet or dry) as the equivalent POR in HEC-FDA to account for the greater uncertainty in future conditions.

Synthesis of experts' opinions: recommendations

Taken together, points made during the group discussions and the experts' written responses suggest that the following steps should be taken to adjust the flood frequency curve used in the hydrologic analysis supporting the Fargo-Moorhead feasibility study:

1. Develop, and use as the basis for the frequency analysis, an unregulated time series. Prior to the addition of significant regulation in the system, the series will be the recorded flows. After regulation was added, the recorded flows must be adjusted to "remove" the effects of regulation in the system. This can be done with the reservoir and channel routing models that the District has available.
2. Develop and use a transform function to convert the derived unregulated frequency function to the regulated frequency function that is required for the risk analysis. This transform function can be developed by simulating system behavior without and with regulation for floods from the POR. As the historical floods may fail to cover adequately the range of flows needed to define the frequency curve well, historical events can be scaled to simulate larger floods. This is consistent with guidance in EM 1110-2-1415.
3. Analyze the unregulated flow series, and divide the current POR into two portions. Suggestions for identifying the "break" between the wet period and the dry period included:
   - Using qualitative judgment, e.g., define the dry period as 1901-1941 and the wet period as 1942-2009; or define the dry period as 1901-1960 and the wet period as 1961-2009.
   - Use statistical tests for homogeneity to determine where to divide the POR. The expert panel did not agree on the statistical tests, but did note work by Villarini, et al.
4. Fit an LPIII distribution separately to the dry components of the split record and the wet component, following generally the guidance in *Bulletin 17B*. Some members of the panel suggested using the total record to estimate the skew coefficient to be used for both components. Others suggested determining the skew coefficients for each portion of the POR separately. If the skew coefficients are close, an appropriately rounded average of the two could be used.
5. Combine the wet and dry curves, and weight the probabilities for continued wet conditions versus a reemergence of dry conditions. Two schemes emerged from the majority of the experts' responses:
   - Transition from wet to dry over time. For example, begin with p(wet)=1 and p(dry)=0 in year 1 of the project, moving to p(wet)=0.5 and p(dry)=0.5 in year 50, or move p(wet) from 1 to 0 over the life of the project.
   - Do not change the probabilities over time, e.g., p(wet)=0.8 and p(dry)=0.2 over the entire 50-year project life.
6. Account for greater uncertainty. One suggestion was to use an equivalent POR in HEC-FDA equal to the number of years of the smaller portion of the POR (either the wet portion or the dry portion).

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Appendix 1. Biographical summaries of EOE participants

Below are brief biographical summaries for the expert panel members; observers; and the technical integrator and facilitator of this expert opinion elicitation.

Expert panel members

Michael Deering, PE, D.WRE. Deering is a Senior Hydraulic Engineer with the Water Resource System Division at the US Army Corps of Engineers (USACE) Hydrologic Engineering Center (HEC) in Davis, CA, where he specializes in the development and application of flood risk management and system analysis software. His technical expertise includes flood risk management with risk analysis, impact analysis, ecosystem restoration, river hydraulics, stream stability and scour, surface water hydrology, water surface profile modeling, floodplain delineations, and hydraulic structures. Deering holds a BS and MS in civil engineering from the University of California, Davis, and is a registered professional engineer in the State of California. Deering is a Diplomate, Water Resources Engineer (D.WRE), a distinction assigned by the American Academy of Water Resource Engineers.

Scott Dummer. Dummer is the Hydrologist-in-Charge for the National Weather Service (NWS) North Central River Forecast Center located in Chanhassen, MN. Prior to his current position, he was the Deputy Chief of the NWS Hydrology and Climate programs in the Western United States. His operational experiences include the Great Flood of 1993, the Red River of the North floods of 1997 and 2009, the 2006 Taum Sauk Dam Failure in southern Missouri, and a devastating flash flood in Franklin County, MO, in 2000. Dummer is a 1993, 2000, and 2003 US Department of Commerce Bronze Medal recipient, and a 2004 NOAA Administrators Award recipient in recognition for his various operational and developmental contributions to the agency. He holds a BS in atmospheric sciences from the University of North Dakota and an MS in water resources science from the University of Kansas.

Robert Hirsch, PhD. Hirsch is a research hydrologist at the US Geological Survey (USGS) National Research Program in Reston, VA. He is a former Associate Director for Water at the USGS, where he was responsible for the water science programs of that agency. These include water-related research, collection of data on rivers and ground water, and assessments of water quantity and quality. Hirsch has a BA in geology from Earlham College, an MS in geology from the University of Washington, and a PhD in geography and environmental engineering from Johns Hopkins University. He has received numerous honors from the federal government and from non-governmental organizations.

Rolf Olsen, PhD. Olsen is a water resources systems engineer with the Corps' Institute for Water Resources in Alexandria, VA. Olsen is currently managing a new Corps program on adaptations to climate change. He has led many studies involving climate change and water resources, including an analysis of the potential impacts of climate change and variability on flood frequency analysis for the Upper Mississippi River system. He has a PhD in systems engineering from the University of Virginia, an MS from the

Pennsylvania State University, and a bachelor's degree from Columbia University. He was a nuclear submarine officer in the US Navy for eight years.

David Raff, PhD, PE. Raff is the technical specialist for the Flood Hydrology and Emergency Management Group at the Technical Services Center within the US Bureau of Reclamation in Denver, CO. Raff is a registered professional engineer in the State of Colorado. He holds a BS in electrical engineering, an MS in rangeland ecosystem sciences, and a PhD in civil engineering. Raff has been co-technical lead for Reclamation's Research and Development Office climate change activities since 2007 and has been active in the development of the Climate Change and Western Water Group. He has authored articles on varied topics, including landform evolution, geomorphology, remote sensing, water supply forecasting, and climate change impacts on assessments of flood frequencies, as well as broader water resources management issues.

Aldo (Skip) Vecchia, PhD. Vecchia is a research statistician with the USGS in Bismarck, ND. His work focuses on understanding and modeling the complex spatial and temporal variability of climate, streamflow, and water quality. He received his PhD in statistics from Colorado State University and, prior to joining the USGS, held faculty positions at the Colorado School of Mines and the University of Florida. He has authored over 50 journal articles and technical reports relating to stochastic hydrology, time series analysis, and statistical modeling of environmental data. In recent years, he has worked closely with the Corps of Engineers, Bureau of Reclamation, FEMA, Environment Canada, and other federal and state agencies on flooding and water quality issues in the Devils Lake and Red River basins.

Observers

Adnan Akyuz, PhD. As the North Dakota State Climatologist, Akyuz provides the public with weather data, weather data summaries, climate summaries, and climate reports. He also serves as director of the North Dakota Agricultural Weather Network and is an assistant professor of climatology in North Dakota State University's Soil Science Department. Akyuz received his PhD from the University of Missouri-Columbia.

Ronald Beyer, PE. Beyer is a Hydraulic Engineer within the Hydrology section of the Omaha District U.S. Army Corps of Engineers Hydrologic Engineering Branch. Beyer began working for the Corps in November 2000. Beyer is a registered professional engineer in the state of Nebraska. In his current position his duties include hydrologic analysis and modeling for flood risk reduction studies and emergency flood response. He is currently working on a hydrologic deficiency study for Fort Carson near Colorado Springs, CO. Recently he completed work on the Levee Certification Study for the Big Sioux River Phase III Levees in Sioux Falls, SD. Beyer has also been involved in the Omaha District portion of the ongoing Portfolio Risk Assessment for the USACE Dam Safety Program. Beyer aided in the spring 2009 flood fight efforts in Bismarck and Jamestown, North Dakota. He has a bachelor's degree in civil engineering and a minor in biology from North Dakota State University.

Greg Hiemenz. Hiemenz is an Environmental Specialist for the Dakotas Area Office in the US Bureau of Reclamation's Great Plains region. The mission of the Dakotas Area Office is to provide technical assistance and leadership in the responsible development and management of water and related resources to enhance the quality of life in both North Dakota and South Dakota. The Area Office manages six dam and reservoir facilities in South Dakota and three facilities in North Dakota. Hiemenz has a BS in biology and an MS in zoology.

David Moser, PhD. Moser is the Chief Economist for the Corps of Engineers. He is Senior Team Leader—Economics at the Corps' Institute for Water Resources (IWR), and Actions for Change National Team Lead for Risk Informed Decision Making. He has also served as Chief of the Navigation and Water Resources Applications Division at IWR. From 1985 to 2002, he was an economist in the Decision Methodologies Division at IWR. Moser has conducted research in economic methods related to benefit-cost analysis and risk analysis methods applied to water resources, and has led the development of several risk assessment computer models. Moser received his BA in economics from Wittenberg University, an MA in economics from the University of Toledo, and a PhD in economics from the University of Cincinnati.

Richard Pemble, PhD. Pemble retired in the spring of 2008 after 39 years as a professor of biology at Minnesota State University, Moorhead. His research interests have focused on the ecology of the Red River Valley region, especially its native grasslands. In 1996, Pemble was recognized for his research on prairies and his contributions to the preservation of Minnesota's native grasslands when he was awarded the Conservation Award from the Minnesota Chapter of The Nature Conservancy. Pemble earned a PhD in botany at the University of California, Davis, an MS in botany at the University of Montana, and a BS in biology and secondary education at Simpson College.

Gregg Wiche. Wiche is the USGS North Dakota Water Science Center Director. He is a member of the International Joint Commission's International Souris River Board and the International Red River Board. He received a BSc in geography from South Dakota State University and an MSc in geography from the University of Alberta. In addition, he completed course work for a PhD in geography and a minor in civil engineering at Louisiana State University. He began his career as a surface-water hydrologist with the USGS in 1978. He has conducted various hydraulic studies including a 2-dimensional bridge-hydraulics study of the I-10 crossing of the Pearl River near Slidell, LA. From 1984-98 he worked on a series of studies to determine the relations between climate variability and water level fluctuations of Devils Lake and streamflow variability on the Red River of the North. From 1988 to 2003 he served as the Surface-Water Specialist for the North Dakota Water Science Center. He has authored more than 30 USGS reports and journal articles.

Technical integrator and facilitator

David Ford, PhD, PE, D.WRE. David Ford is president of David Ford Consulting Engineers, Inc. He is an internationally recognized expert in hydrologic and environmental engineering and water resources planning and management. Ford has served as a consultant to the Corps of Engineers, National Weather Service, government agencies in India, Portugal, Indonesia, and Romania, the United Nations, World Bank, USAID, state and local governments across the US, and to engineering firms worldwide. Ford ghostwrote the following Corps of Engineers documents: Engineer Manual

(EM) on risk-based analysis for flood-damage reduction studies, EM on hydrologic engineering requirements for flood-damage reduction studies, chapters for the flood-runoff analysis EM, chapter on system theoretic models for the EM on flood forecasting, and technical reference manual and applications guide for HEC-HMS. Ford has a BS in civil engineering, an MS in engineering, and a PhD in water resources systems and hydrologic engineering.

Appendix 2. Protocol for Fargo-Moorhead EOE, Sept. 28-29, 2009

The Fargo-Moorhead EOE was planned and implemented in accordance with these three guidance documents:

- *Technical guide for using expert opinion elicitation in support of USACE risk assessments*, USACE Dam Safety Risk Management Center (2009).
- *A practical guide on conducting expert-opinion elicitation of probabilities and consequences for Corps facilities*, IWR Report 01-R-01 (2001).
- *Methods for expert-opinion elicitation of probabilities and consequences for Corps facilities*, IWR Report 00-R-10 (2000).

The Corps documents describing the EOE process are geared specifically toward Corps risk assessments for civil works infrastructure projects in which the answers sought are generally specific numerical values. In the Fargo-Moorhead EOE, the experts were asked to describe a method for arriving at an answer, rather than the answer itself. Nevertheless, the Fargo-Moorhead EOE conformed closely to the procedures described in the Corps guidance.

The *Technical guide* defines two levels of EOE: Level I is a simplified procedure for preliminary studies, and Level II is a more robust procedure for highly specialized issues or when extensive localized expertise is required. The Fargo-Moorhead EOE was a Level II procedure.

Participants in a Level II EOE include:

- A team of specialized experts who submit their opinions in writing.
- A group of knowledgeable observers who contribute insight and experience to the panel's discussion.
- A technical integrator and facilitator (TIF).
- Additional participants who provide specific information, such as project background information.

The *Technical guide* provides an overview of the EOE process. At the outset of the EOE meeting, the following items are described or clarified:

- The EOE process.
- The goals to be accomplished in the current EOE.
- Definitions and assumptions pertinent to the discussion.
- The questions to be answered.

Once the first question is clearly defined, each expert provides a response to that question without influence of the others.

After the experts turn in their answers, those answers are shared with the EOE participants. A group discussion follows, with experts explaining their answers and others in attendance able to ask questions and offer their perspectives and insight.

Following the group discussion, the experts are asked the same question one more time. Again, they write down their answers and submit them to the TIF.

After the experts turn in their final answers to a question, that question is "closed," and the EOE participants move on to the next question. This pattern of *preliminary question-response-discussion* followed by *final question and response* is repeated for each question until all the questions to be covered in the EOE are completed.

Appendix 3. Agenda of Fargo-Moorhead expert opinion elicitation, Sept. 28-29, 2009

Agenda of Fargo-Moorhead EOE, September 28-29, 2009, St. Paul, MN

Est. time	Activity/topic	Presenter/ participant	Approx. duration
Sept. 28 8:00	Welcome, logistics, overview, introductions	Ford	50 min.
8:50	Break (10 minutes)		
9:00	Describe Fargo-Moorhead project, including discharge frequency curve now used	Corps	50 min.
9:50	Break (10 min)		
10:00	Describe the climate trend	Corps, USBR	30 min.
10:30	Describe Corps R & U procedures	Ford	20 min.
10:50	Break (10 min)		
11:00	Provide overview of EOE process, goals to be accomplished, training example	Ford	30 min.
11:30	Present contextual information for question 1, then pose question 1	Ford	15 min.
11:45	Expert panel members write, submit answers; others break for lunch; Ford collects answers from panel	Expert panel	15 min.
12:00	Lunch; assess need to adjust agenda	Ford, Corps	60 min.
1:30	Present range of answers to question 1	Ford	15 min.
1:45	Expert panel members explain answers to question 1	Expert panel	20 min.
2:05	Discuss question 1	Expert panel + observers	75 min. (breaks TBD)
3:10	Summarize discussion points; expert members submit post-discussion answers; break when finished	Ford	20 min.
3:40	Present contextual information for question 2, then pose question 2	Ford	15 min.
3:55	Expert panel members write, submit answers, take break; Ford collects answers	Expert panel	20 min.
4:15	Present range of answers to question 2	Ford	15 min.
4:30	Expert panel members explain answers to question 2	Expert panel	20 min.
4:50	Begin panel discussion on question 2	Expert panel + observers	40 min.
5:30	Adjourn for day; debrief; adjust day 2 agenda as needed	Ford; Corps	

Agenda of Fargo-Moorhead EOE, September 28-29, 2009, St. Paul, MN

Est. time	Activity/topic	Presenter/ participant	Approx. duration
Sept. 29 8:00 a.m.	Review previous day	Ford	15 min.
8:15	Resume discussion on question 2	Expert panel + observers	35 min.
8:50	Summarize discussion points; expert members provide post-discussion answers, take break (others break until 9:20)	Expert panel	30 min.
9:20	Present contextual information for question 3, then pose question 3	Ford	15 min.
9:35	Expert panel members write and submit answers, take break; Ford collects answers	Expert panel	30 min.
10:05	Present range of answers	Ford	15 min.
10:20	Expert panel members explain answers to question 3	Expert panel	20 min.
10:40	Discuss question 3	Expert panel + observers	75 min.
11:55	Summarize discussion points; experts provide post-discussion answers	Ford	
Noon	Lunch; assess need for agenda adjustment	Corps; Ford	60 min.
1:00	Present contextual information for question 4, then pose question 4.	Ford	15 min.
1:30	Expert panel members write and submit answers; Ford collects answers (others free until 1:45)	Expert panel	30 min.
2:15	Present range of answers	Ford	15 min.
2:30	Expert panel members explain answers to question 4	Expert panel	20 min.
2:50	Discuss question 4	Expert panel + observers	75 min. (break TBD)
4:05	Summarize discussion points; expert members provide post-discussion answers; break if needed	Ford	25 min.
4:30	Wrap up	Corps; Ford	

Appendix 4. Digest of the Fargo-Moorhead EOE

The Fargo-Moorhead expert opinion elicitation (EOE) was held on Sept. 28-29, 2009, in St. Paul, MN.

Per Corps EOE guidance, approximately four weeks prior to the EOE, the experts and observers were sent a read-ahead information packet that contained the following:

- Information about the Fargo-Moorhead feasibility study.
- A description of the apparent trend in increasing Red River flood magnitude and frequency.
- An overview of the EOE process.
- A brief overview of risk and uncertainty analysis in Corps planning studies.
- A CD of relevant research documents provided by St. Paul District staff.
- A list of references.

At the start of the 2-day Fargo-Moorhead EOE meeting, the TIF, David Ford, reminded all the participants of the following points:

- The Red River of the North presents a unique hydrologic and hydraulic record, and therefore the results of this EOE are not necessarily going to set precedent for other regions of the country.
- The time scale of a Corps project is a matter of decades: the life of a project is considered to be 50 years, and the economic analysis often focuses on the first 20-30 years, as this has the greatest impact on the discounted benefits and costs.
- The recommendations that result from this EOE must be implemented within the time, budget, and resource constraints of this project.

Ford also presented information about the EOE process and the Corps' risk and uncertainty procedures and requirements. Ford explained that the Corps' standard of practice for flood risk analysis is described in detail in Engineer Manual (EM) 1110-2-1619, *Risk analysis for flood damage reduction studies*. The procedure described in that manual—and used by District staff for the Fargo/Moorhead study—requires computation of performance indices for proposed risk reduction plans, for current and future conditions, considering the uncertainty about inputs to the computation. The indices computed for each plan are then compared to indices similarly computed for the without-project condition to determine the plan's accomplishments. The economic contributions are evaluated by computing a value of expected annual damage (EAD) over the anticipated life of the project. Changes are accounted for in the computation if hydrologic, hydraulic, and economic conditions change over the span of the project. The flood flow frequency curve at the location of interest is a key input to the risk analysis.

St. Paul District staff presented information about the Corps' flood risk reduction alternatives for the Fargo-Moorhead region, hydrologic and hydraulic analyses related to the Red River of the North and its tributaries, and the apparent climate trend toward an increase in magnitude and frequency of flood events in this region.

After the background information was presented, Ford posed the first question to the experts. The experts wrote their responses on carbonless copy paper. They submitted one copy of each answer to the TIF, and kept the other copy so they could refer to it during the discussion period that followed.

The experts' responses to the first question were shared with the participants and a group discussion followed. Each expert was given an opportunity to explain his answer, and the observers and others were encouraged to ask questions and contribute pertinent information.

Following the group discussion, the experts were asked to respond to the same question again in light of the discussion. As before, they wrote their answers on carbonless carbon paper. Each expert kept one copy for future reference and submitted the other copy to the TIF.

When all the experts had turned in their final responses to the first question, the question was closed, and the TIF proceeded with the next question. For the Fargo-Moorhead EOE, a total of four questions were posed.

Background information presented at the EOE

Background information presented at the Fargo-Moorhead EOE included an overview of the flooding situation in the Fargo-Moorhead metropolitan area and summaries of the hydrologic and hydraulic analyses conducted for the St. Paul District's Phase 2 Fargo-Moorhead flood risk reduction project feasibility study.

Flooding in Fargo-Moorhead

Craig Evans, a Senior Planner with the St. Paul District, provided an overview of the flooding situation in the Fargo-Moorhead metropolitan area and information about the current feasibility study, which began in September 2008. The goal of the study is to develop a regional system to reduce flood risk. The alternatives being evaluated include non-structural measures, flood walls, levees, diversion channels, and flood storage. The final selection of an alternative is scheduled to take place in December 2009, and the feasibility study is scheduled for completion in December 2010.

Evans made these points in his presentation:

- Emergency flood fights have been successful in Fargo and Moorhead, but the area remains vulnerable to flooding.
- Both the 1997 and 2009 flood events came close to overwhelming the emergency levee systems, and many homes and other structures outside the levees were damaged.
- The Red River of the North has exceeded the National Weather Service flood stage in 50 of the past 106 years and in every year from 1993 through 2009.
- A 500-year event would flood nearly the entire city of Fargo and a large portion of the city of Moorhead. (Moorhead sits on relatively higher ground than Fargo.)

- Flooding occurs both from rivers and from local drainage due to large rainfall events that overwhelm storm drainage systems.

Hydrologic analysis

Dan Reinartz, PE, a Senior Hydraulic Engineer with the St. Paul District, summarized the hydrologic analyses that are described in detail in the Hydrology appendix of the feasibility study. Significant points included the following:

- The total drainage area at the USGS streamflow gage for the Red River at Fargo is 6,800 square miles, of which 2,175 square miles are considered noncontributing. Of the remaining 4,625 square miles, 1,405 square miles are controlled by White Rock Dam and Orwell Dam.
- The continuous period of record (POR) dates back to May 1901, with historic flood information available for events occurring in 1882 and 1897.
- The largest observed flow occurred on March 28, 2009, and had an instantaneous peak discharge of 29,400 cfs. This is considered to be approximately a p=0.01 event.
- In the 2009 event, cold temperatures during the rising limb of the flood hydrograph arrested the melt and runoff process and stemmed what would likely have been a p=0.005 event, as occurred upstream in Hickson and Wahpeton.
- The second highest flood of record occurred on April 17, 1997, with an instantaneous peak discharge of 29,000 cfs.
- The annual instantaneous peak discharge frequency relationship for the Red River at Fargo was developed using period of record flows available at the Fargo streamflow gaging station.
- Because of regulation effects from the upstream reservoirs, adjustments in the recorded data set were required to obtain a homogeneous record based on the current regulated condition.
- To develop the natural peak discharge frequency curve:
    - Actual recorded flows were used up to the year 1942.
    - Flows from 1942 to 2009 were adjusted to the natural condition by routing flows from Lake Traverse and Orwell Dam. The gage outflows at these locations were "reverse routed" through the respective reservoirs to arrive at the natural condition inflows.
    - The incremental local flows at the downstream computation points at Wahpeton, Hickson, and Fargo were determined by routing the observed flows and subtraction.
    - The mean daily flows were adjusted to estimate the natural instantaneous annual peak flows. For the period prior to 1942, the actual recorded instantaneous peaks were used. For the period 1942-2009, the adjustment was accomplished by regression of recorded mean daily peaks and instantaneous peaks.
    - The resulting annual peak flows were then input into HEC-FFA for analysis of discharge frequency.

- To develop the regulated peak discharge frequency curve:
  - Recorded annual instantaneous peak flows were adopted for the period 1942-2009.
  - Annual instantaneous peak flows were determined for the period prior to 1942 from a regression analysis of recorded mean daily peak flows versus simulated mean daily flows.
  - Recorded natural mean daily flows for 1902-1942 were read on the simulated mean daily scale to arrive at the regulated mean daily flow.
  - The regression relationship that was used in the natural condition computation was used to adjust the annual mean daily regulated peak flows to annual instantaneous regulated peak flows.
- The POR instantaneous peak flows were plotted with the analytical natural discharge-frequency curve, and a graphical curve was drawn through the points.
- To aid in drawing the upper portion of the curve, synthetic 100-year, 200-year, and 500-year events were routed through the upstream reservoirs and then routed and combined with downstream flows for both the with- and without-reservoirs conditions. The natural condition analytical frequency curve was used to associate a representative frequency and the corresponding regulated flows were plotted at that same frequency.
- For the computation points at Wahpeton and Hickson, the regional skew from the USGS publication for generalized skew coefficients for Minnesota was used. For the computation points at Fargo, Halstad, and Grand Forks, the Grand Forks station skew coefficient with the Grand Forks station mean-square error was used.

Hydraulic analysis

Mike Lesher, Senior Hydraulic Engineer with the St. Paul District, gave an overview of the structural alternatives being considered and summarized the hydraulic analyses done for the Phase 2 feasibility study. Significant points included the following:

- Diversion channels on both the Minnesota and North Dakota sides of the Red River of the North are being considered.
- In the discharge-frequency curve input in HEC-FDA, an equivalent record length of 119 years was used. (This is the average of the systematic record [109 years] and historical period or record [128 years].)
- The discharge-frequency curve input for HEC-FDA was extrapolated to a p=0.0001 event.
- A discharge-frequency transform relationship was developed for the natural and regulated flows at Fargo.

Evidence of nonstationarity in the period of record

Dan Reinartz provided an overview of the data signifying that the frequency and magnitude of flooding has increased in recent decades in the Fargo-Moorhead metropolitan area. Important points included:

- Annual runoff volume, shown in terms of departure from the average, was relatively low during the decades when the Fargo-Moorhead metropolitan area was being developed (roughly the 1930s through the 1960s), and begins to show an increasing trend from at least the mid-1960s to the present.
- For the period 1600-1962, the upper Midwest was a region showing persistent drought, according to Stockton and Boggess (1979).
- The period from 1902 to about 1940 is marked by the relatively rare occurrence of annual peak flows significantly greater than the annual mean flow. On the other hand, the period from about 1940 through 2009 is marked by the relatively frequent occurrence of annual peak flows significantly greater than the annual mean flow.
- The POR appears to be nonhomogeneous, with a period of low annual peak flows in the early decades of the 20th century, and an unmistakable increasing trend in the annual peak flow at Fargo from about 1942 to present.
- Work by St. George, et al. (2001) shows an apparent periodicity in wet and dry periods as measured by the deviation from mean annual precipitation from 1961-1990 for reconstructed annual precipitation at Winnipeg from 1409 to 1998. This pattern would suggest that the current relatively wet period will persist in the future; how long it will last is uncertain, however.
- Trends in peak streamflow for the Red River of the North at Grand Forks, ND, show an overall increasing trend line from 1882-2007. These data also show a possible periodicity, with relatively high peak streamflow values at the turn of the last century, relatively low peak streamflows in the 1930s, and an upward trend from the 1940s to the present. The recent high flows are not unprecedented.

Group discussion following presentation of background information

After the presentation of the background information, a number of experts and observers had questions and comments about what they had seen. In most cases, questions were posed in a rapid-fire manner, as the participants began thinking about some of the issues. Questions and statements of opinion (paraphrased) from this discussion included:

- Were geomorphological changes accounted for in the routing? (They were not.)
- Is overbank storage upstream? (There is.)
- A large amount of uncertainty surrounds the historical flood events of the late 19th century; is more error introduced by including them or omitting them?
- *Bulletin 17B* presumes climatic invariance.
- Is the EOE really discussing climate change or is it discussing nonstationarity? Those are not necessarily the same thing.
- The discharge-frequency curve is strongly negatively skewed, and distributional assumptions may be a source of concern.

- Will the trends in precipitation and streamflow continue into the future, or are the trends seen now manifestations of past changes, with not much more change in the future?
- Freezing/frost plays an important role in flood events: freeze attenuates the flow, for example. In the most recent flood event, the frost let out prior to the first crest, which allowed water to soak into the ground.
- "Something is happening" at Oakport to cause a shift in stages.
- At around the 20-year event (about 20,000 cfs), flood fighting begins.
- Do flood damages in Fargo-Moorhead top out at some point, for example, at the 500-year event?
- Do changes in uncertainty about the discharge frequency curve affect the findings of feasibility of flood risk reduction measures?
- Has uncertainty about the unregulated flow to regulated flow transform function been described?
- The Corps is making the assumption that there is a single curve that is uncertain, but there may be more than one curve, or a single curve that's always changing.
- The Corps' risk analysis is beginning to include other indices besides expected annual damage, such as loss of life.
- How does the length of the period of analysis (20 years? 30 years?) compare to the time scale of climate change?
- The Corps needs to project some climate. Is it the current state, or another state?
- Starting in 1980 or so, it is clear that precipitation increases in this region.
- The record seems to show periods of stability, then periods of variability, repeated over and over.
- Pre-1940, precipitation and evapotranspiration data are quite different than post-1940.
- High floods appear rather stable in the last 50 years, but small floods seem to have disappeared from the record.
- Precipitation right before snow is important. Floods usually occur in the spring. Precipitation is trending faster than evapotranspiration. A significant increase in cool season precipitation is apparent.
- Small changes in precipitation can result in large changes in soil moisture/ accumulated storage.
- What effect does even a small increase in temperature have? Will evapotranspiration increase and balance out the effect of increased precipitation? It would take many years for soil moisture to evaporate.
- Abrupt climate changes have happened at all scales over time. Tree rings and other climate proxies show historical climate change. So, global warming may be contributing to the trends in this region, but it need not be invoked to explain abrupt changes in precipitation and streamflow.

Panel questions, discussions, and responses

Following presentation of the background material and the discussion that followed, the TIF presented the experts with the first question.

Question 1

Is it likely that climate change will have a significant impact on the flood flow frequency curve during the life of the proposed flood risk reduction project for Fargo, ND-Moorhead, MN?

Initial responses to Question 1

The experts were evenly divided in response to Question 1: three experts gave a qualified "yes," and three experts gave a qualified "no." Several responses questioned whether the term "climate change" meant an anthropogenic increase in greenhouse gases leading to global warming. Several stated that climate change, which they defined as taking place over a much longer time frame, would not have an effect on flood frequencies over the time period of analysis (20-30 years). All responses acknowledged that natural decadal-scale variability was present in the data. Many responses commented that this variability increases the uncertainty about flood frequency over the next 20-30 years. In sum, the answers seemed to say this: if climate change means global warming over thousands of years, no, it will not impact flood frequency over the life of this project. If climate change means natural variability over a time scale of decades, yes, it probably will impact flood frequency over the life of this project, but we do not know how to predict the impact very well.

Discussion

The group discussion following the preliminary responses to Question 1 essentially repeated the content of the responses. The experts and observers began to narrow their focus and define relevant terms as they traded ideas. Representative comments included:

- Climate change takes place over thousands of years; state changes take place over tens of years.
- It is more likely that the climate will change than that it will not change.
- We do not understand all the physical factors of climate.
- "Weather" is a sample from the climate probability distribution.
- El Nino and the Southern Oscillation cause "weather," not climate trends.
- The question posed today is not about short-term forecasting; it is about predicting long-term flood probabilities.

At the end of this discussion, the TIF proposed asking Question 1 again, but in two parts:

(a) Has historical climate change/variability been accounted for in an appropriate manner in the proposed frequency analysis?

(b) If climate has been addressed appropriately to date, do we need to consider climate change in the flow frequency curve?

Final responses to Question 1

To part (a), there were five "no" votes and one "yes" vote. Most responses said that the current analysis does not acknowledge the lack of homogeneity in the flood frequency and flood magnitude data.

To part (b), there were five "yes" votes and one "no" vote. Most responses focused on the need to account for the uncertainty in future projections of precipitation and flood flow frequency.

Question 2

How will the frequency curve change?

Initial responses to Question 2

In answering this question, the experts began to focus on the idea that the period of record shows two states, a relatively dry period early in the 20th century and a relatively wet period later in the 20th century. Some experts stated that it was likely the current wet period would persist for some period of time in the future, while others stated that there is no way to know what will happen in the future. A consensus emerged about the need to account for greater uncertainty, whether or not the curve itself is changed.

Discussion

The concept of two states in the POR led to a discussion about transition probabilities. As one participant put it, "drought begets drought, and wet begets wet. But, on the other hand, it could transition into the other state at any time." The group talked about strategies for analyzing the project alternatives under the two states, such as analyzing each alternative under each state separately and comparing the results. There was a suggestion to truncate the POR, thereby increasing the uncertainty in the analysis. The skew factors required by *Bulletin 17B* were discussed, as well. Lastly, Corps staff shared flood discharge versus damage information for the Fargo-Moorhead metropolitan area. The information that was written on a flipchart at the EOE meeting is reproduced in the table below.

Table 3. Flood damage versus discharge for Fargo-Moorhead metro area

Q (cfs)	Old P[1]	Damages
18,000	0.05	$114 M
23,000	0.02	$524 M
31,000	0.01	$1.97 B
45,000	0.004	$4.33 B
57,400	0.002	$5.73 B
--	0.001	$ 6.58 B

1. 1. The computations used to arrive at these values do not include data for 2009.

Final responses to Question 2

Question 2 was re-phrased slightly for the final response: Assuming we have the right frequency curve, how will that change in the next 50 years due to climate change?

All of the experts stayed with their initial answers to Question 2. Some added a bit of clarification or explanation. Several responses reiterated the idea of dividing the entire POR into two periods of record; one suggested using just 1960-2009 for the equivalent POR. Several also reiterated the need to account for greater uncertainty.

Question 3

What are the practicable alternatives for accounting for the impact of the change?

Initial responses to Question 3

All the experts' responses showed that they were thinking of a two-state or mixed-population system, with the POR divided at some point in the mid-20th century between the earlier relatively dry period and the more recent relatively wet period. Alternatives suggested included:

- Truncating the POR and using only the last 30-40 years of observed annual maximum peaks.
- Developing separate "recent/wet" and "past/dry" curves, and estimating transition probabilities for future years.
- Developing a stochastic water-balance model for generating annual flows on the basis of monthly precipitation, evaporation, and basin storage, and using the annual flows to condition the flood frequency curve.
- Using the regulated POR (1942-present) to develop all the frequency curves.
- Using the currently proposed curve for the early years of the project life, and then "switching" or "jumping" to a "climate change" curve at some point in the life of the project.
- Analyzing each alternative flood risk reduction measure under two separate scenarios: (1) the entire POR, and (2) the most recent five decades only, then selecting an alternative that performs reasonably well under both, rather than trying to maximize NED under one or the other.
- Continuing to use the currently proposed curve.
- Dividing the entire POR into two portions at some mid-20th century point to be determined either qualitatively or through statistical tests for homogeneity; using transition probabilities, e.g., from the starting point of the observed record or from the St. George rainfall analysis (≈600 years); and using a Monte Carlo framework to combine the two curves into a simulated flood frequency/damage curve.

Discussion

During this discussion, the experts and observers refined their views of the two-state approach. Representative comments included:

- Using the currently proposed frequency analysis is not responsible because it is obvious something has changed.
- Presenting an analysis using the currently proposed curve is important, and should be discussed in the feasibility report.

- Several statistical tests are available to determine the homogeneity of the POR.
- Using only the most recent portion of the POR is a special case of using both portions of the POR, where one portion has a probability of occurrence = 0 and the other portion has a probability of occurrence = 1.
- Using both portions of the POR is less of a departure from *Bulletin 17B* than using only the most recent portion. If we think of this situation as a mixed population problem, it may be analogous to hurricane vs. no-hurricane years or snowmelt vs. thunderstorm precipitation situations.
- Transition periods present a lot of uncertainty. If the "climate change switch turns on," soil moisture and small depressional lakes would slow down low flows. We do not know how much memory is in the system at wet-to-dry transitions.
- HEC-FDA does handle two frequency curves.
- A key parameter in the economic analysis is the number of years before the climate switch is turned on.
- Maybe a "climate switch" is not the right way to look at it. It is clear that low frequency variability wanders around. Instead of a switch, there is a conditioning ratio. Say, for example, that current floods are two times as high as over the entire POR. There is uncertainty in evaporation, etc. We should generate multiple futures, some going up or down faster than others.
- Where we put the dividing line in the POR is key. We do not want to artificially divide it so that we include only big floods in one set of the data.
- Do the analysis on both sets of data and let the stakeholders decide which outcome they want to use or how to weight them. (The downside is that local stakeholders will probably want the bigger project.)
- We are in a wet period of a climate-variable system, and we should treat it as probable that we will stay wet using the entire 600 years of precipitation record.
- Using a Markov chain is too complex.
- *Bulletin 17B* requires mixed populations that are of equal probability and independent. Once you introduce dependency, it goes beyond Corps guidance.
- Use a marginal approach: what is the probability that it will stay "wet" for the next 20 years?
- Use long-range dependence and autocorrelation to get a reduced POR. But, autocorrelation is an alias or artifact of the trend. We really need to widen the confidence bands.
- We need a function that starts at p=1 for wet and decreases the p over time, drawing from the wet, based on some portion of the historical record.
- Plotting International Panel on Climate Change (IPCC) temperature and precipitation projections may be used as a method to determine the POR

break point and the probability we will remain in the wet period for the study period.

Final responses to Question 3

In their final answers, the experts further refined their preliminary responses to Question 3. Areas of consensus became clear, such as dividing the entire POR. Opinions continued to diverge about what precisely to do with the POR once it was divided. Responses included:

- Experts, not stakeholders, should determine the break point in the full record to determine the two smaller portions of the POR.
- Experts, not stakeholders, should determine the probability of being in each of the two states ("wet" versus "dry").
- Use 1942-2009 as the POR for developing all discharge-frequency curves. The added uncertainty from using a shorter POR is a good outcome of this, especially in that it will increase the upper confidence curve.
- Use a weighting scheme to transition from the "wet" frequency curve to the full-record curve over time.
- Divide the POR into two portions, "wet" and "dry," then re-combine the two frequency functions, with "wet" having greater than or equal weight to "dry." (Suggested weights ranged from 0.8:0.2 to 0.5:0.5 wet to dry.)
- Do a scenario analysis for three distributions: entire POR, mixed distribution, and wet period distribution, and keep them separate for the economic analysis.
- Run HEC-FDA with current conditions and one most likely future condition.
- Run HEC-FDA with the current frequency curve, and then run it with a "wet period" frequency curve. Apply year-to-year weightings, and determine a combined EAD outside of HEC-FDA.

Question 4

Of the alternatives available, which is best for this particular application, given the limitations imposed by the urgent need to reduce risk in Fargo/Moorhead?

Initial responses to Question 4

Generally, the experts' responses to Question 4 did not differ substantively from their final responses to Question 3. The responses to Question 4 acknowledged the time constraints present for the Fargo-Moorhead feasibility study. Representative responses included:

- Two frequency curves should be considered from the observed record. The dividing line in the POR can be defined subjectively, or if time allows, using statistical tests for homogeneity.
- The two curves can be combined subjectively, although, if time allows, some quantitative basis (e.g., historical precipitation records) for their combination would be preferred.
- The final result should be weighted in favor of a continued wet period, with allowance for the occurrence of a dry period not to exceed p=0.5.

- The final curve should have quantities greater than the current curve has.
- The final curve should have wider confidence intervals than the current curve has.
- Ideal approaches to weighting include exploring the use of a Markov chain, using the 600-year rain record, or probability/percentage of dry periods occurring in next 50 years.
- Quick subjective probabilities would be wet p= 0.75 and dry p= 0.25.
- Use the current distribution based on the entire POR, and include all sources of uncertainty in the economic analysis.
- Do economic analyses for three scenarios: entire POR, mixed population, and wet period only.
- Think beyond the usual maximization of NED as the criteria for selecting an optimum design; account for greater uncertainty in decision-making process.
- Make separate HEC-FDA runs using the current frequency curve and a "wet period" frequency curve. Prepare a spreadsheet that combines weighted EADs incrementally to include combined uncertainties.
- Treat the entire POR as a mixed population, and divide it into a wet period and a dry period using statistical analyses for homogeneity. Develop two separate flow functions, weight them appropriately, then combine them. Weight the probability of continued "wet" conditions at 0.8, and dry conditions at 0.2.
- Use two frequency curves, one for the period 1960-2009, and the other for the entire POR. Combine the two curves into one curve for each future year using specified probabilities that transition gradually from p=1 for the wet curve and p=0 for the dry curve at the beginning of the analysis period to p=0 for the wet curve and p=1 for the dry curve at the end of the analysis period.
- Do a sensitivity analysis using just the wet period for the entire analysis period.
- Take a mixed population approach as follows:
  - Break the POR into two portions: 1942-2009 and 1902-1941, based on a paper by Villarini, Serinaldi, Smith, and Krajewski in Water Resources Research, Vol. 45, WO8417, 2009. These authors did a change point analysis for change in the mean based on the Pettitt test, and the Fargo record shows a significant step change at 1942.
  - Do LPIII analysis on each period, but to estimate skew, take all the data values (the log discharges) and subtract the group mean, divide by the group standard deviation from the appropriate group and then compute a skewness on all 108 values.
  - Set a subjective estimate of the marginal probabilities of being in the wet (later) population at 0.8 and a probability of the dry (earlier) population at 0.2.

- For sensitivity analysis, try setting the probability of the dry population at 0.37 (its proportion in the current data set) and also at zero (meaning no return to the dry state).

Discussion

Following the preliminary responses to Question 4, it became clear that, if the Corps wants to use the strategy emerging from the EOE to develop a new Fargo-Moorhead flow frequency curve, these questions need to be answered:

- How should the current POR be split into two portions?
- How should the skew coefficient be determined for the two portions?
- How should the two separate curves be combined to arrive at a single curve?
- How should uncertainty be accounted for?

The predominant ideas expressed during the group discussion were as follows:

- Split the POR this way: 1902-1941 and 1942-2009, based on Villarini, et al.
- Split the POR this way: 1902-1959 and 1960-2009, based on subjective observation and (unnamed) relevant studies.
- Do statistical tests for homogeneity.
- Use the entire POR (1902-2009) as one population, and use the "wet period" (starting at 1942 or 1960 or some other year to be determined) as another population.
- Skews for each population should be calculated independently, and should account for uncertainty. If the two values are close, the average of the two values could be used.
- Make separate runs in HEC-FDA for each population, then combine/post-process them outside of HEC-FDA.
- Weight "wet" versus "dry" over the life of the project: either weights remain the same each year, or weights change year to year (with "wet" getting relatively more weight in the early years of the project life).
- The equivalent POR is the input for uncertainty in HEC-FDA, so the question is: how do we specify the equivalent POR to account for uncertainty in the two populations? And, is that enough to account for uncertainty in the final curve?

Final responses to Question 4

The experts did not change their preliminary answers, except to comment further on the issue of uncertainty. All reiterated their earlier approaches. The final answers can be summarized as follows:

- Run each curve (wet population and dry population) separately in HEC-FDA for full 50-year economic analysis period. This can be done with either a single weighting of wet and dry or multiple increments with different weightings. Each separate run will account for uncertainty in that particular population. Need to investigate further how to describe uncertainties in the distribution of EAD and project performance.

- Account for uncertainty by selecting the equivalent POR as the number of years in the shorter of the two populations. Run each distribution separately in HEC-FDA, then combine them with the appropriate weighting. Recommend p=0.8 for wet and p=0.2 for dry.
- Use accepted techniques for uncertainty analysis.
- Use a mixed distribution with three weighting alternatives: same as in the POR, an intermediate weight, and a weight that assumes only the most recent (wet) period will continue to occur. Do an economic analysis for each scenario. Compare to the current distribution (which assumes stationarity). Explain to the public and planners the uncertainty inherent in the flow frequency curve, and try to choose an alternative that does well, even if we have mischaracterized the curve.
- Use a mixed population model, with the first being 1942-2009 (wet), and the second being 1901-1941 (dry). Do not include historical floods (of the late 19th century). Start with p=1 for wet in year 1 of the project, then decrease linearly to p=0.5 in year 50 of the project.
- Define break in POR with statistical test of homogeneity or peer-reviewed published value, if available. Consider both populations within LPIII framework. Large historical floods from the 19th century can be included in either population at the discretion of the project engineer. Analysis should be done on natural flows, and re-regulated later. It would be preferable to use a weighting function that begins with p=1 for wet and p=0 for dry in year 1, moving over the course of the project life to p=0.5 for wet and p=0.5 for dry in year 50. Less preferable: 0.75 for wet and 0.25 for dry unchanged over the 50 years. Increase uncertainties upwards before economic analysis; probably will have to be done subjectively, e.g., a 25% increase.

The verbatim text of the experts' preliminary and final responses is included as Attachment 6 to this memorandum.

Attachment 5. Background information: USACE PowerPoint slides

Fargo-Moorhead Metro Feasibility Study - Hydrology

Presenter Name: Daniel Reinartz

Presenter Title: Hydrologic Engineer

Duty Location: St. Paul District

Date of Presentation: 28 September 2009

US Army Corps of Engineers
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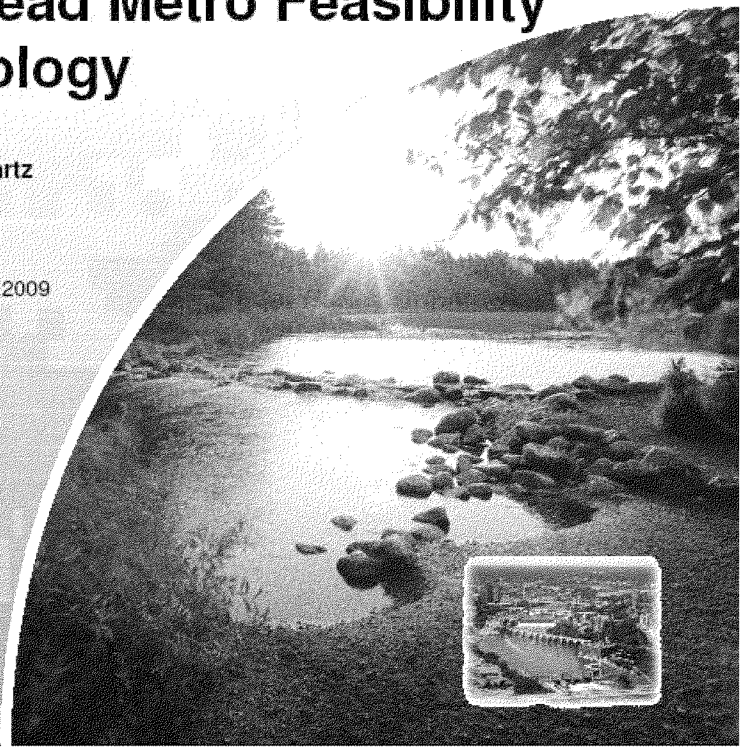
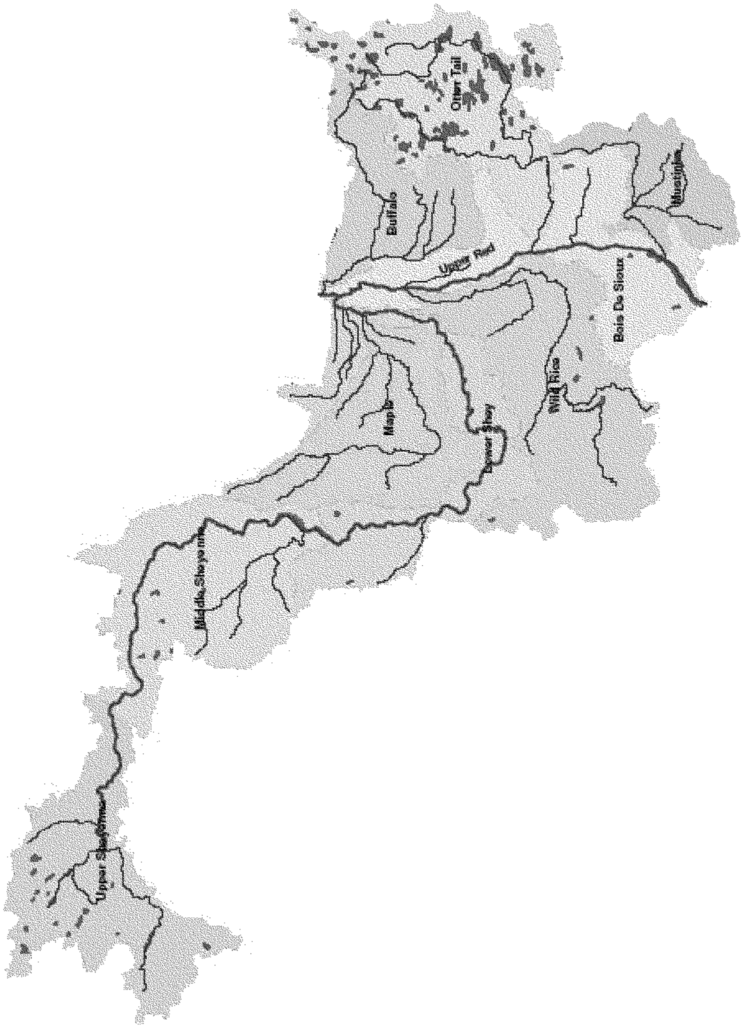



Red River Mainstem Streamgages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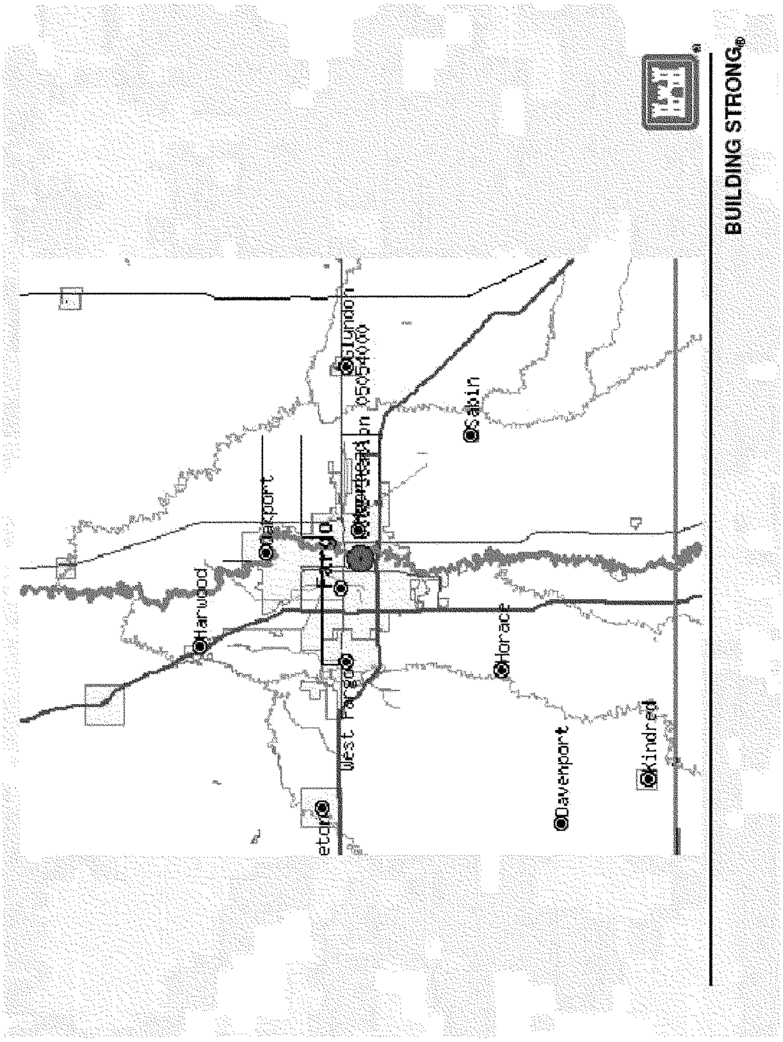
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Harwood
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West Fargo
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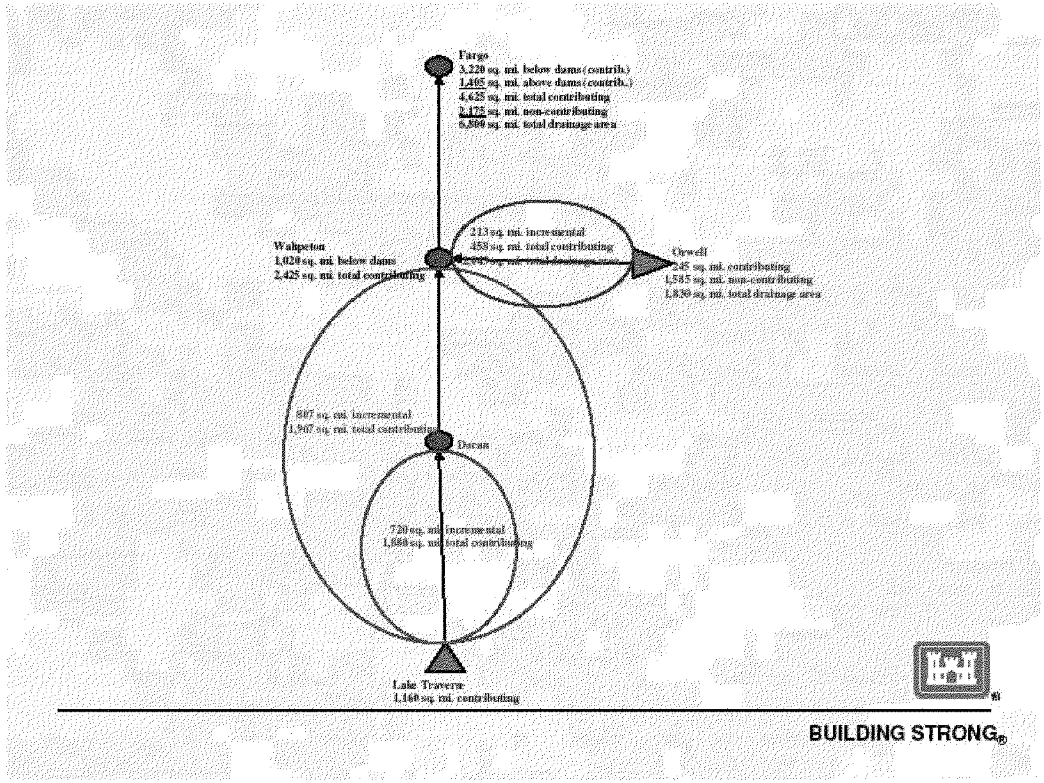
Davenport
Kindred
Sabin



Fargo
3,220 sq. mi. below dams (contrib.)
1,405 sq. mi. above dams (contrib.)
4,625 sq. mi. total contributing
2,175 sq. mi. non-contributing
6,800 sq. mi. total drainage area
213 sq. mi. incremental
458 sq. mi. total contributing
Wahpeton
1,020 sq. mi. below dams
2,425 sq. mi. total contributing
Orwell
245 sq. mi. contributing
1,585 sq. mi. non-contributing
1,830 sq. mi. total drainage area
807 sq. mi. incremental
1,967 sq. mi. total contributing
Doran
720 sq. mi. incremental
1,880 sq. mi. total contributing
Lake Traverse
1,160 sq. mi. contributing
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Upstream Reservoirs

- ORWELL RESERVOIR
  - Built in 1953
  - 13,100 ac.-ft. flood control storage
  - 39 mi. u/s of Wahpeton
  - 135 mi. u/s of Fargo
- Lake Traverse/White Rock Dam
  - Built in 1942
  - Purpose: Flood control & water conservation
  - 137,000 ac.-ft. flood control storage
  - 30 mi. u/s of Wahpeton
  - 125 mi. u/s of Fargo
  - 1997 only event that reservoir releases contributed to peak @ Wahpeton

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Period of Record

- POR: 1882, 1897, 1902 – 2009
- Natural Condition:
  - Before Orwell & L. Traverse
  - without Dams Condition
  - 1882-1942
- Regulated Condition = 1942 – 2009
- POR is non-homogeneous
- POR must be adjusted to current homogenous condition

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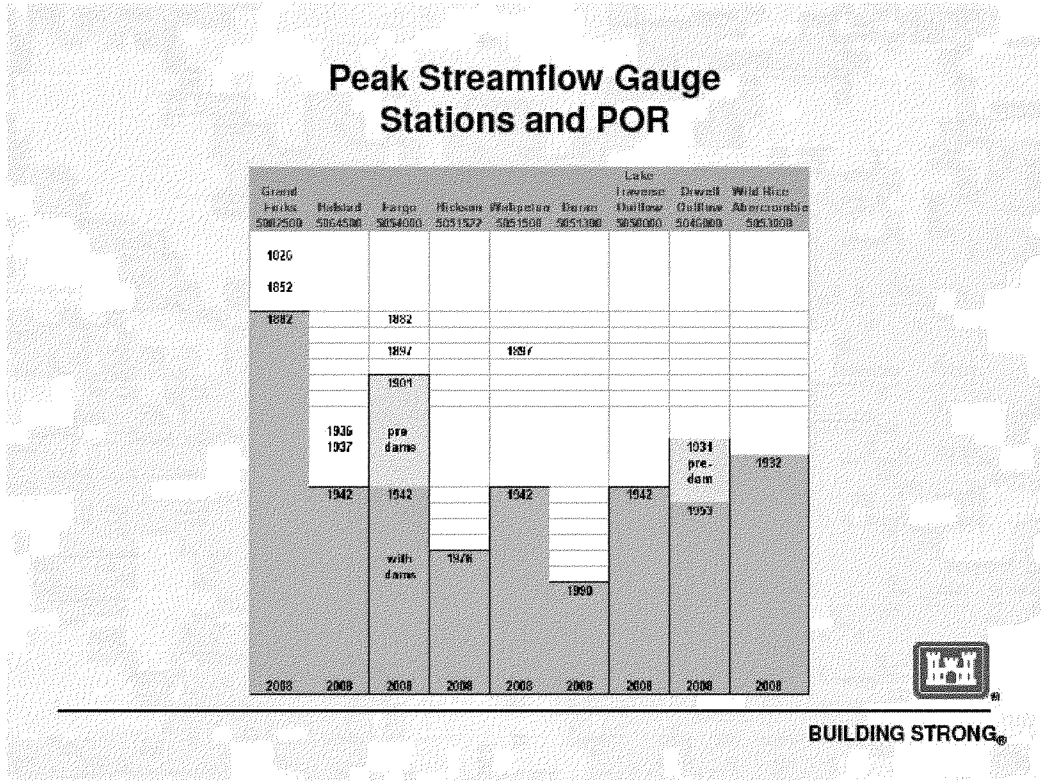
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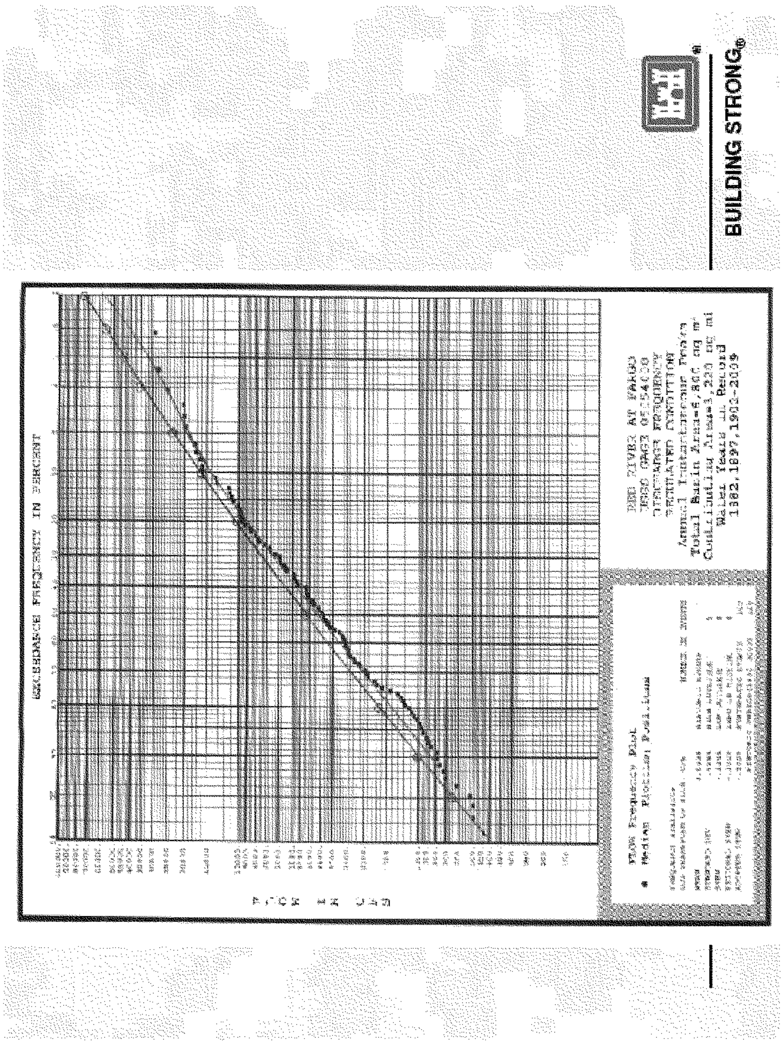
Wahpeton 5051500
Doran 5051300
Lake Traverse Outflow 5050000
Orwell Outflow 5046000
Wild Rice Abercrombie 5053000
1826
1852
1882
1882
1897
1897
1901
1936
1937
pre dams
1942
1942
with dams
1942
1942
1976
1990
1931
pre-dam
1953
1932
2008
2008
2008
2008
2008
2008
2008
2008
2008
BUILDING STRONG®

Method Overview

- Develop Natural Peak Q-frequency
  - Mean Daily
  - Instantaneous
- Develop REGULATED Peak Q-frequency
  - Mean Daily
  - Instantaneous
- Plot Both Curves Together
  - Plot Natural Analytically LPIII
  - Plot Instantaneous Graphically
  - Use Hickson Peak Q-frequency as guide

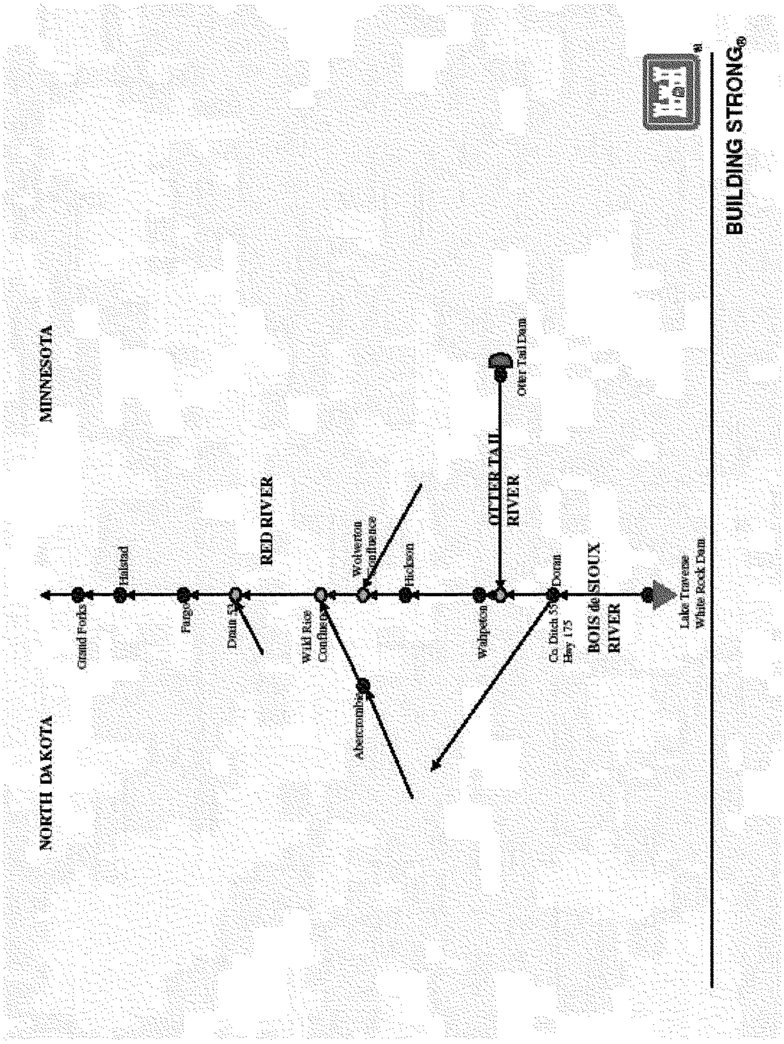
BUILDING STRONG®


EXCEEDANCE FREQUENCY IN PERCENT
BUILDING STRONG

Develop Natural Peak Q-Frequency

- Use existing record: 1902 to 1942
- Adjust existing regulated pks to natural pks: 1942 to 2009
- Do this using Hec-5 (reservoir simulation model)
- "reverse route" outflows from u/s dams and then route and combine flows d/s to Fargo
- Develop Q-Frequency analytically by LPIII for full record: 1902 to 2009
- Two additional significant events 1882 & 1897
- Systematic record = 109
- Historic record = 128

BUILDING STRONG®


MINNESOTA
NORTH DAKOTA
RED RIVER
OTTER TAIL RIVER
Otter Tail Dam
Grand Forks
Halstad
Fargo
Drain 53
Wild Rice Confluence
Wolverton Confluence
Hickson
Wahpeton
Abercrombie
Doran
Co. Ditch 55 Hwy 175
BOIS de SIOUX RIVER
Lake Traverse White Rock Dam
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Develop Natural Peak Q-Frequency (cont.)

- Use Median Plotting Position
- (m-.3)/(n+1-.3-.3)

- M = order number
- N = number of years

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Develop Natural Peak Q-Frequency (cont.)

- Develop Instantaneous Peaks
- Regress Instant. Pks vs. MD Pks for observed record
- 1942 – 2009
- Apply same relation to simulated MD pks

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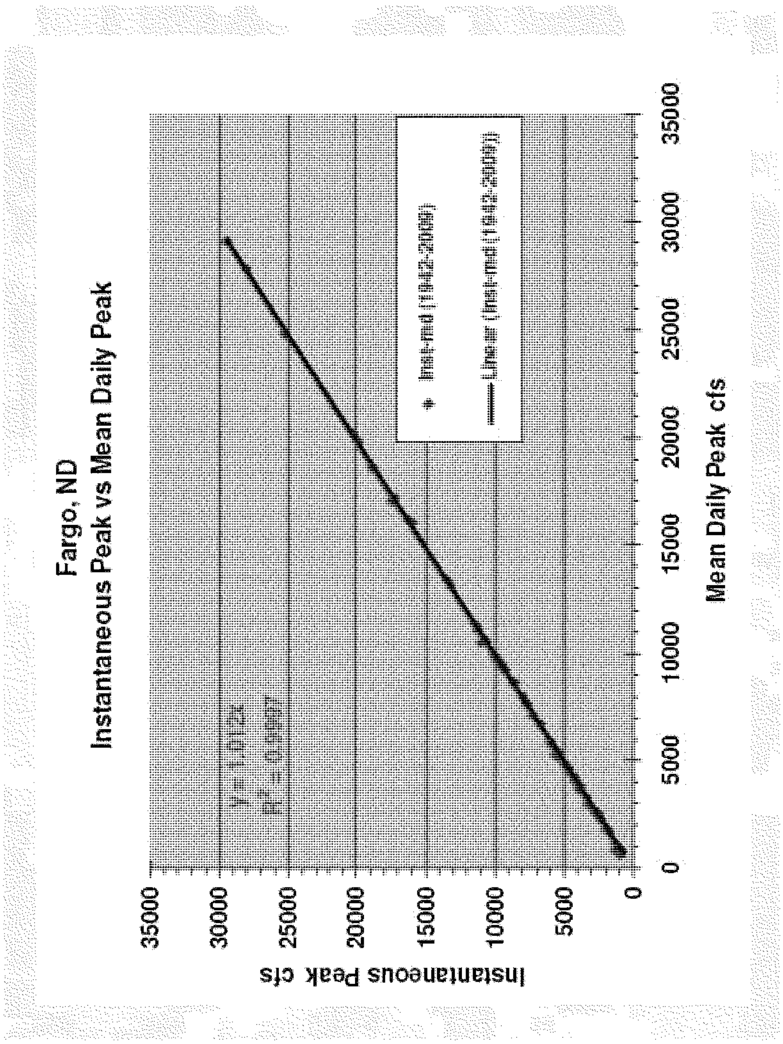

Fargo, ND
Instantaneous Peak vs Mean Daily Peak
Instantaneous Peak cfs
Mean Daily Peak cfs
0
5000
10000
15000
20000
25000
30000
35000
Inst-md (1942-2009)
Linear (Inst-md (1942-2009))

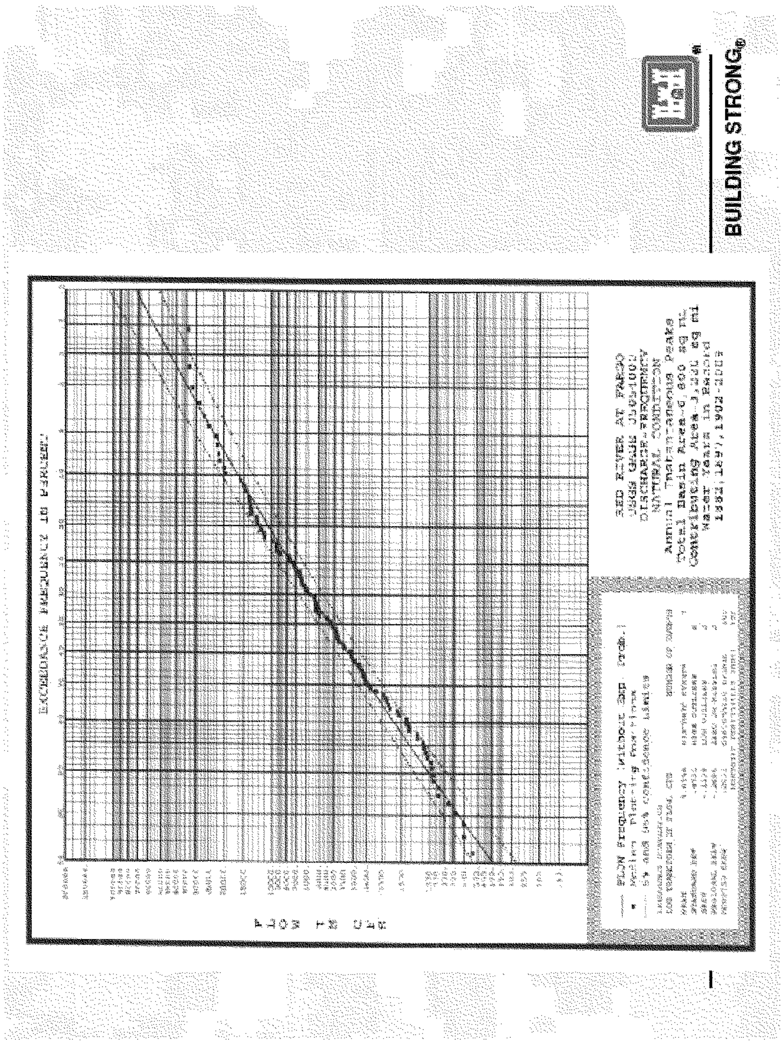
Develop Natural Peak Q-Frequency (cont.)

- 1 Historic Event = 1897 (largest event since 1882)
- 5 High Outliers

- INSTANTANEOUS PEAK
- ORDERED EVENTS

RANK	WATER YEAR	FLOW CFS	MEDIAN PLOT POS
1	2009	33753.	.55
2	1969	32978.	1.32
3	1997	31768.	2.10
4	2001	28829.	2.88
5	2006	26610.	3.66
6	1897	25000.	4.44
7	1978	22401.	5.29
8	1989	22029.	6.20
9	1952	21585.	7.11
0	1979	21318.	8.03
1	1882	20000.	8.94

BUILDING STRONG®


EXCEEDANCE FREQUENCY IN PERCENT
FLOW IN CFS
RED RIVER AT FARGO
BUILDING STRONG

Method Overview

- Develop Natural Peak Q-frequency
  - Mean Daily
  - Instantaneous
- Develop REGULATED Peak Q-frequency
  - Mean Daily
  - Instantaneous
- Plot Both Curves Together
  - Plot Natural Analytically LPIII
  - Plot Instantaneous Graphically
  - Use Hickson Peak Q-frequency as guide

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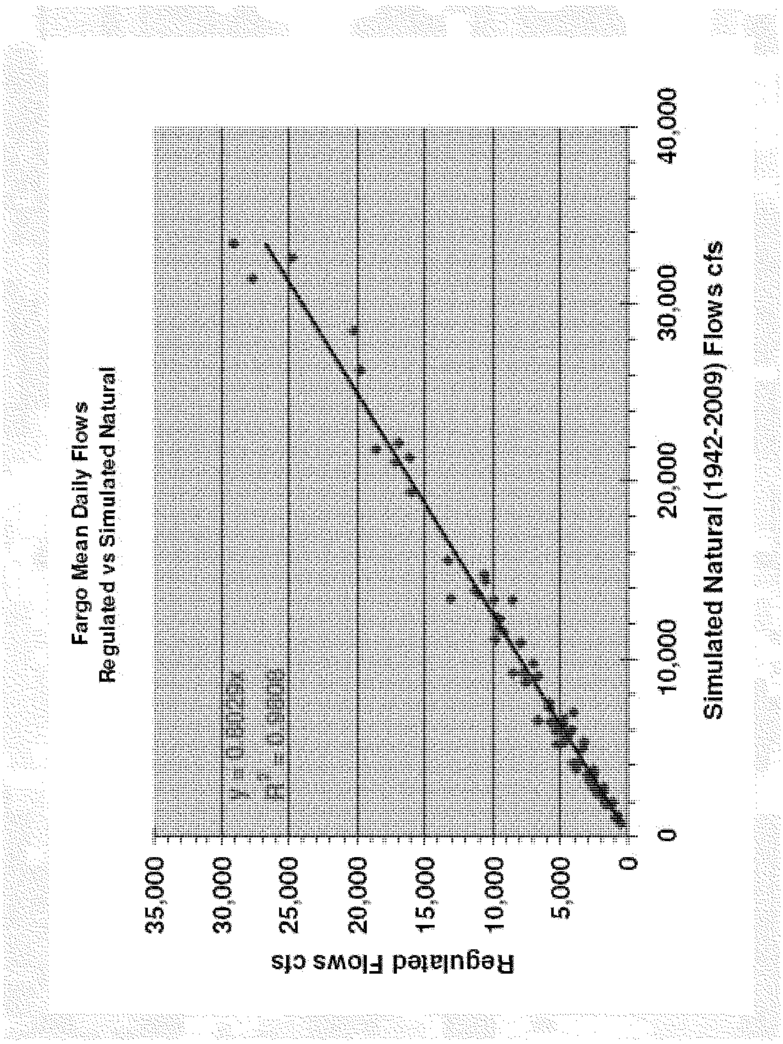
Develop Regulated Peak Q-Frequency

- Adjust POR 1902-1942 for regulated condition
- Regress Existing (regulated) MD Pks vs. simulated MD pks
- Develop graphical Q-Frequency for full record
- Plot with Natural conditions curve
- Use Median plotting position

BUILDING STRONG®


Fargo Mean Daily Flows
Regulated vs Simulated Natural
Regulated Flows cfs
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
0
10,000
20,000
30,000
40,000
Simulated Natural (1942-2009) Flows cfs

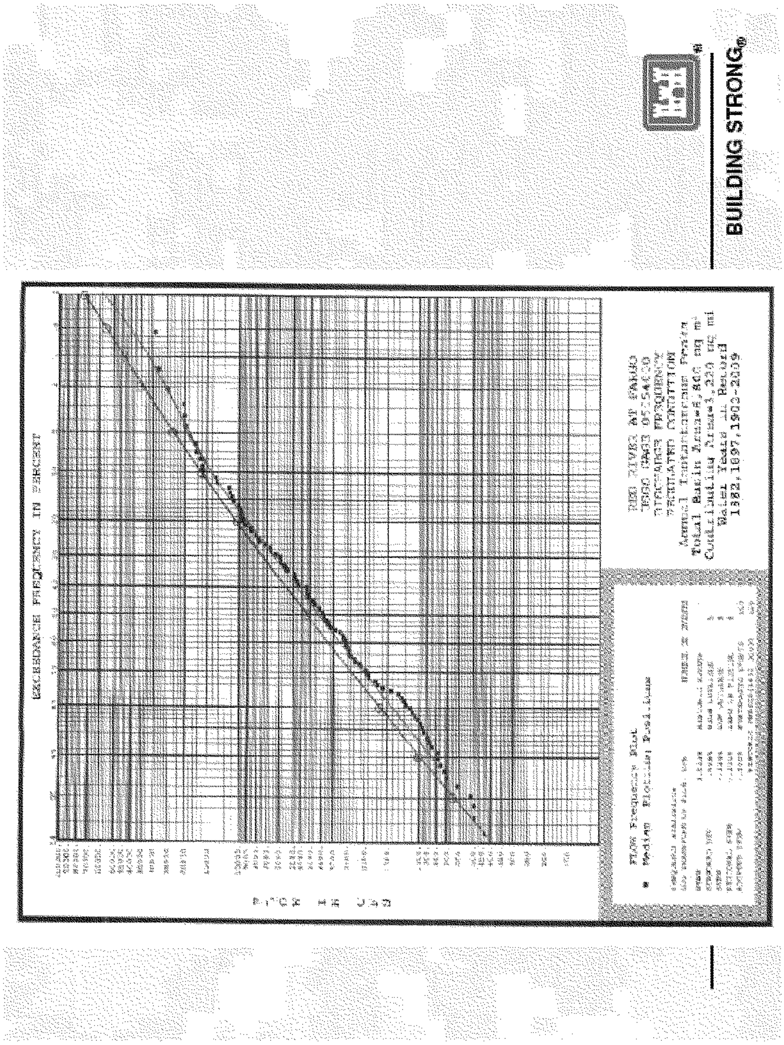
Develop Regulated Peak Q-Frequency (cont.)

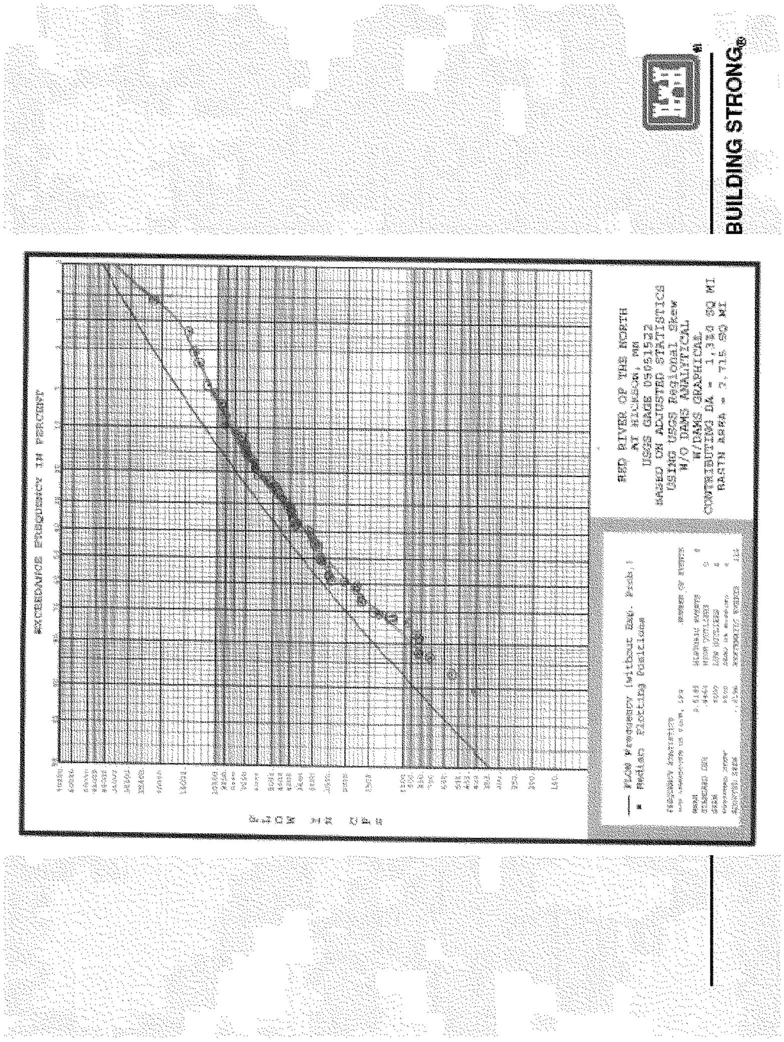
- 1 Historic Event = 1897 (largest event since 1882)
- 5 High Outliers

ORDERED EVENTS

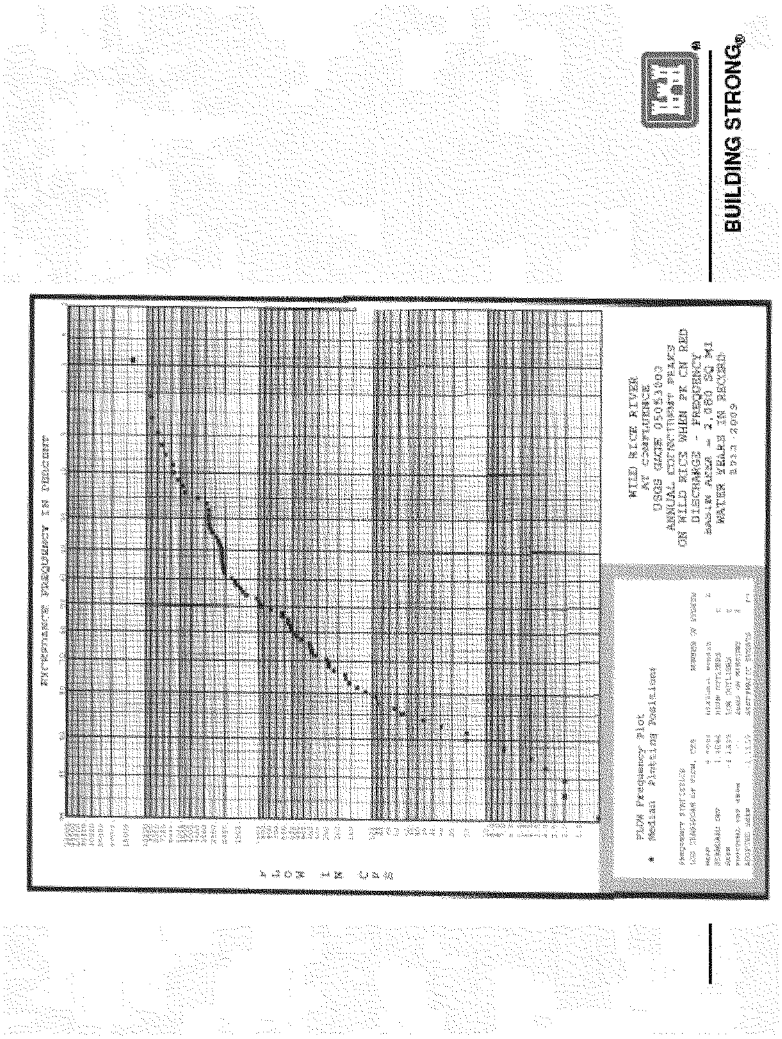
RANK	WATER YEAR	FLOW CFS	MEDIAN PLOT POS
1	2009	29400.	.55
2	1997	28000.	1.32
3	1969	25000.	2.10
4	2001	20300.	2.88
5	1897	20073.	3.66
6	2006	19900.	4.44
7	1989	18900.	5.29
8	1978	17500.	6.20
9	1979	17300.	7.11
10	1952	16300.	8.03
11	1882	16058.	8.94

BUILDING STRONG®


EXCEEDANCE FREQUENCY IN PERCENT
FLOW IN CFS
FLOW Frequency Plot
RED RIVER AT FARGO
DISCHARGE FREQUENCY
REGULATED CONDITION
Water Years in Record
BUILDING STRONG



EXCEEDANCE FREQUENCY IN PERCENT
FLOW IN CFS
Median Plotting Positions
RED RIVER OF THE NORTH
BASED ON ADJUSTED STATISTICS
W/O DAMS ANALYTICAL
W/DAMS GRAPHICAL
BUILDING STRONG


BUILDING STRONG®
WILD RICE RIVER
AT CONFLUENCE
ANNUAL INSTANTANEOUS PEAKS
DISCHARGE - FREQUENCY
EXCEEDANCE FREQUENCY IN PERCENT
FLOW IN CFS
FLOW Frequency Plot
Median Plotting Positions

Skew Weight

- Use Regional skew = MN USGS Map
  - Wahpeton
  - Hickson
- Use Grand Forks Station Skew with GF station MSE
  - Fargo
  - Halstad
  - Grand Forks

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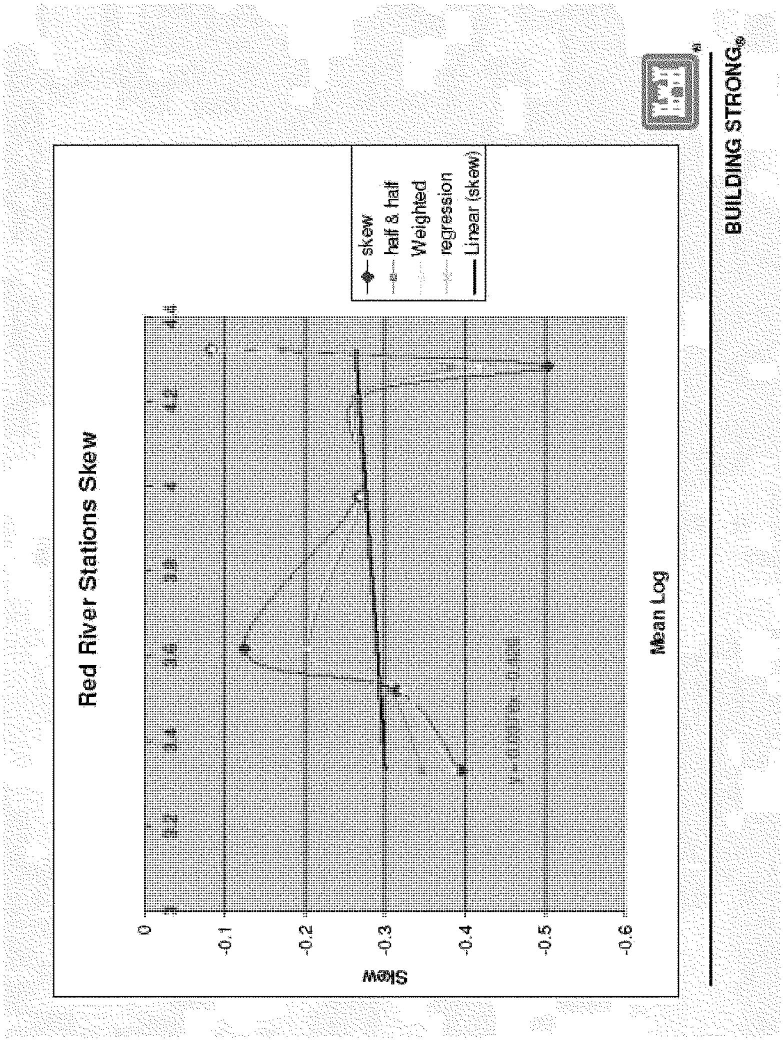
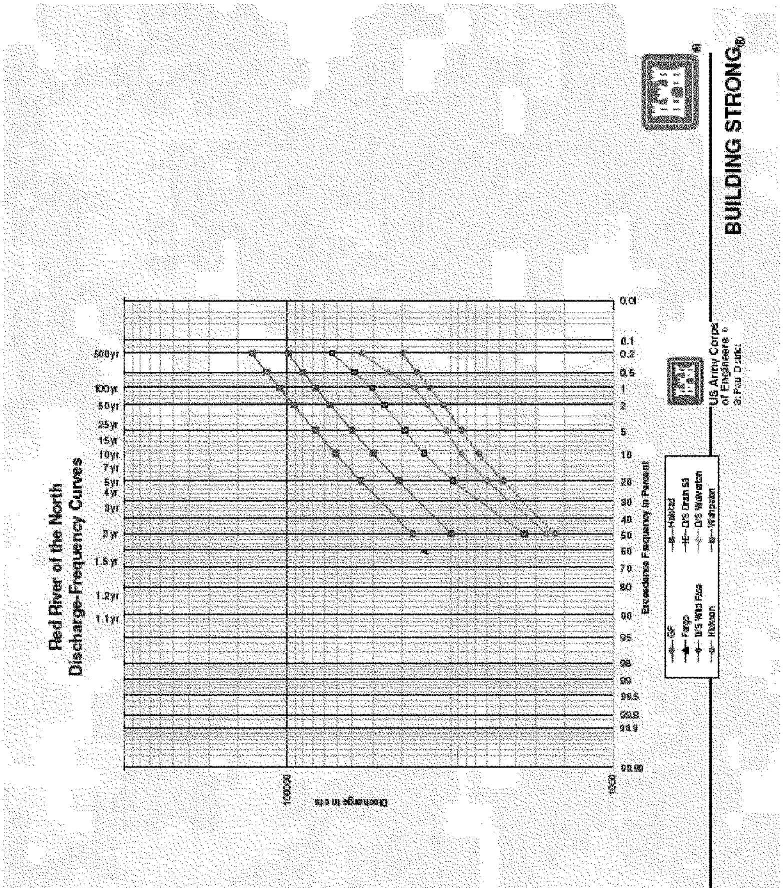

Red River Stations Skew
Skew
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
3
3.2
3.4
3.6
3.8
4
4.2
4.4
Mean Log
skew
half & half
Weighted
regression
Linear (skew)
BUILDING STRONG®


Red River of the North
Discharge-Frequency Curves
Exceedance Frequency in Percent
Discharge in cfs
US Army Corps
of Engineers
BUILDING STRONG

Method Overview

- Develop Natural Peak Q-frequency
  - Mean Daily
  - Instantaneous
- Develop REGULATED Peak Q-frequency
  - Mean Daily
  - Instantaneous
- Plot Both Curves Together
  - Plot Natural Analytically LPIII
  - Plot Instantaneous Graphically
  - Use Hickson Peak Q-frequency as guide

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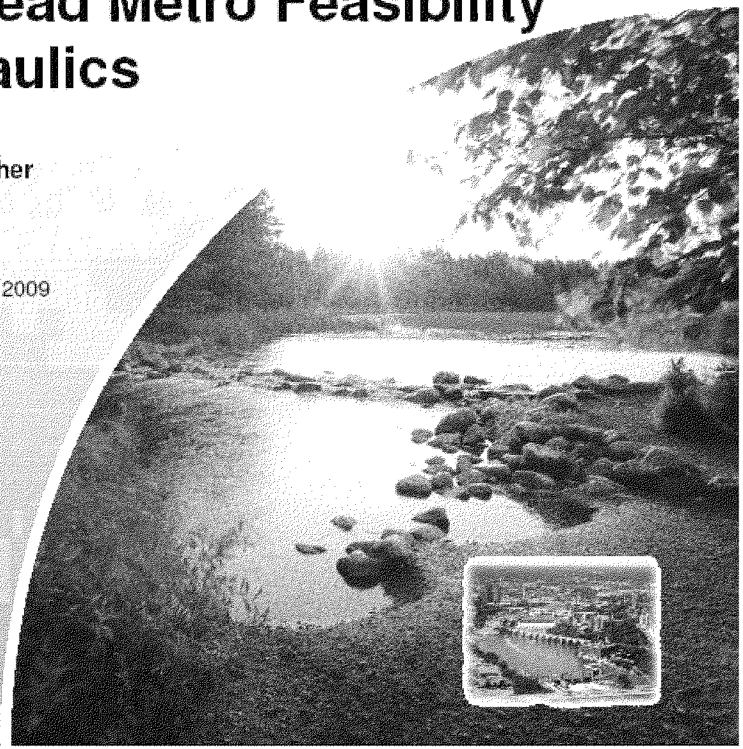
Fargo-Moorhead Metro Feasibility Study - Hydraulics

Presenter Name: Michael Lesher

Presenter Title: Hydraulic Engineer

Duty Location: St. Paul District

Date of Presentation: 28 September 2009



US Army Corps of Engineers
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Fargo-Moorhead Metro Feasibility Study

- Alternatives Overview
- H&H Inputs for Risk & Uncertainty Analysis

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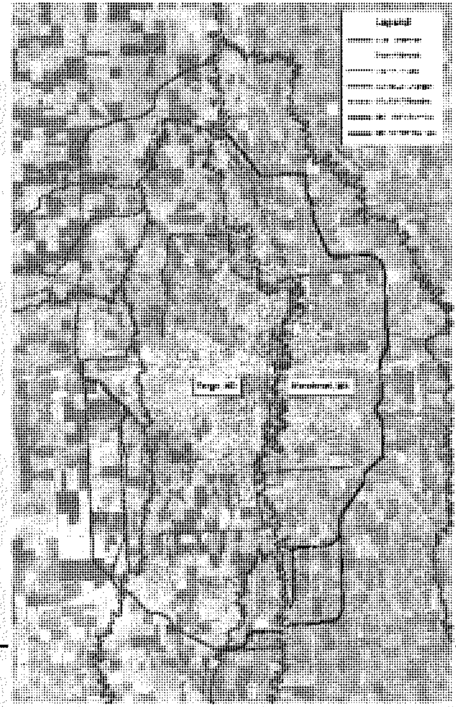
Alternatives Overview



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Diversion Channel Capacities Considered

Minnesota Short & Long

- 25,000 cfs
- 35,000 cfs
- 45,000 cfs

North Dakota West

- 35,000 cfs
- 45,000 cfs

North Dakota East

- 35,000 cfs

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H&H Inputs for Risk & Uncertainty Analysis

- Discharge-Frequency Curve with Transform Relationship
- Elevation-Discharge Curve with Uncertainty

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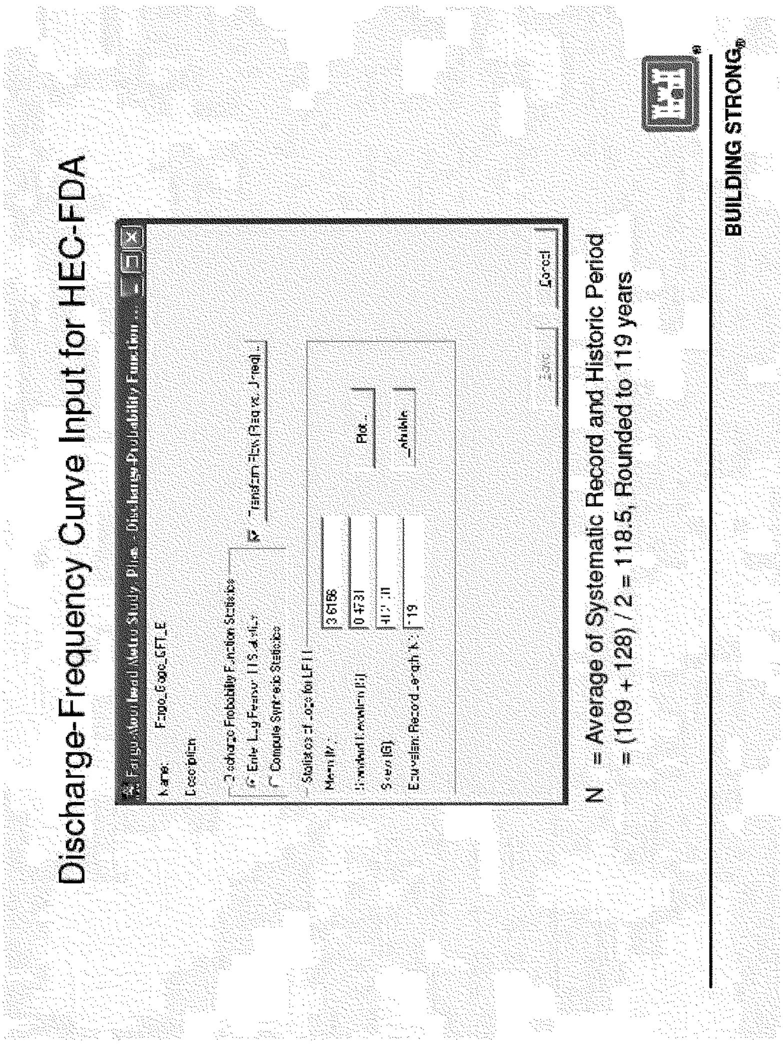
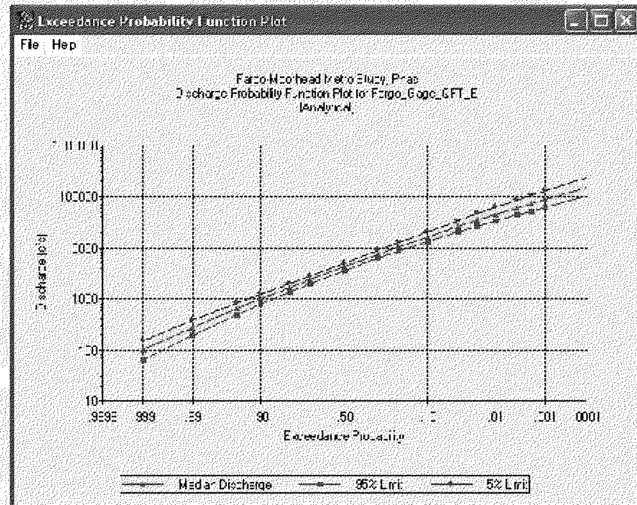

Discharge-Frequency Curve Input for HEC-FDA
Plot...
Cancel
N = Average of Systematic Record and Historic Period
= (109 + 128) / 2 = 118.5, Rounded to 119 years
BUILDING STRONG®

Discharge-Frequency Curve Input for HEC-FDA



Discharge-Frequency Curve
Defined to 0.01%, (10,000-Year) Event

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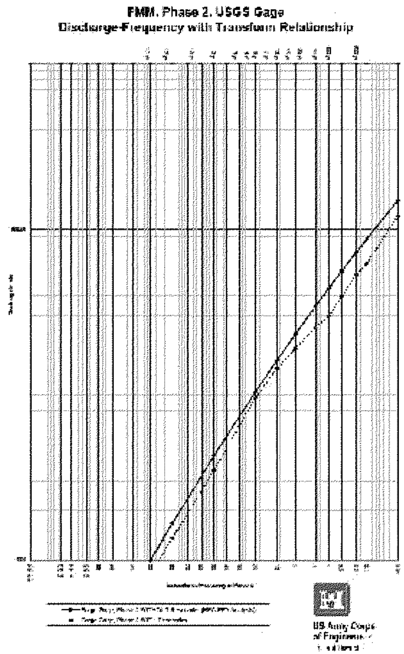
Discharge-Frequency Transform Relationship



FMM, Red River of the North		
DATA Frequency (in percent)	Phase 2 Fargo Natural	Phase 2 Fargo Regulated
0.01	149,000	120,000
0.1	87,500	62,000
0.2	72,600	53,000
0.5	55,400	39,000
1	44,200	30,000
2	34,300	25,500
5	23,200	19,000
10	16,200	14,500
20	10,400	9,600
50	4,280	3,500
80	1,670	1,360
90	1,000	829
95	647	550
99	279	251

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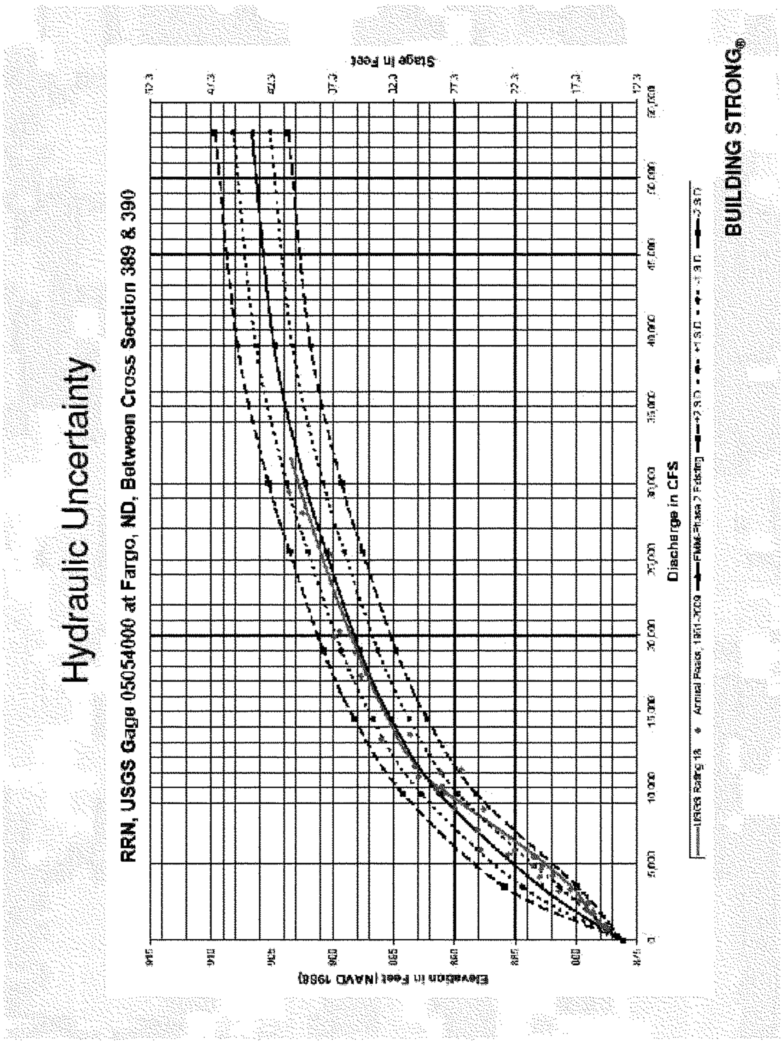
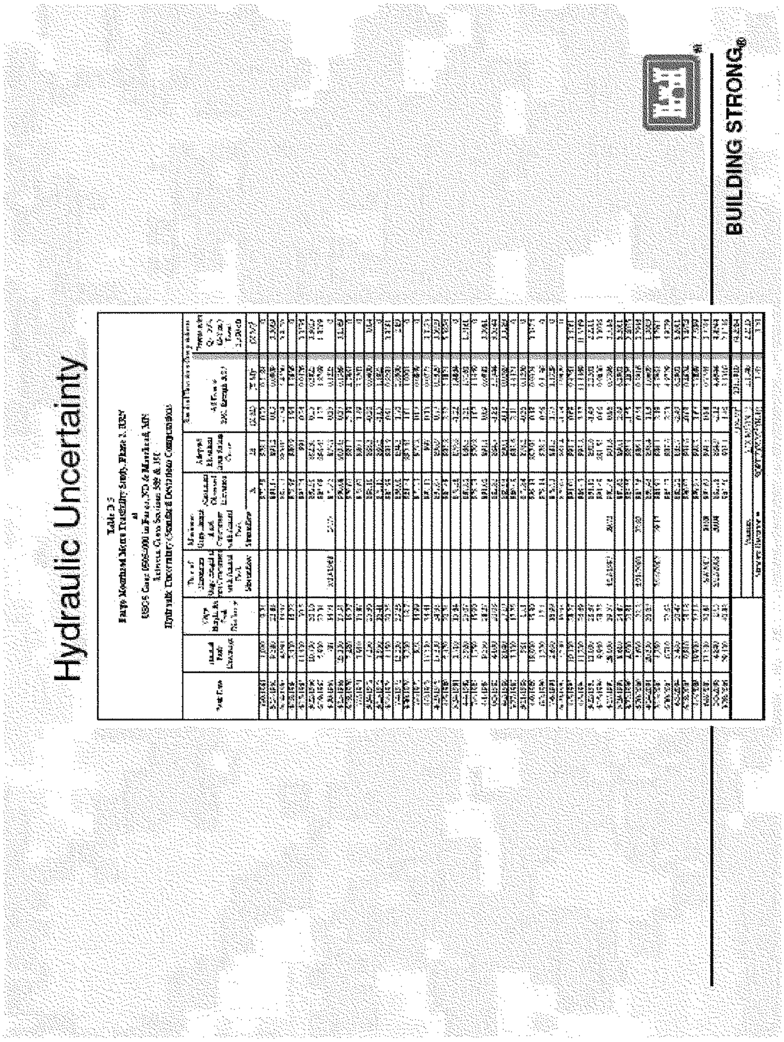

Hydraulic Uncertainty
RRN, USGS Gage 05054000 at Fargo, ND, Between Cross Section 389 & 390
Elevation in Feet (NAVD 1988)
Stage in Feet
Discharge in CFS
BUILDING STRONG®


Hydraulic Uncertainty
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Fargo-Moorhead Metro Feasibility Study

Questions?

Comments?

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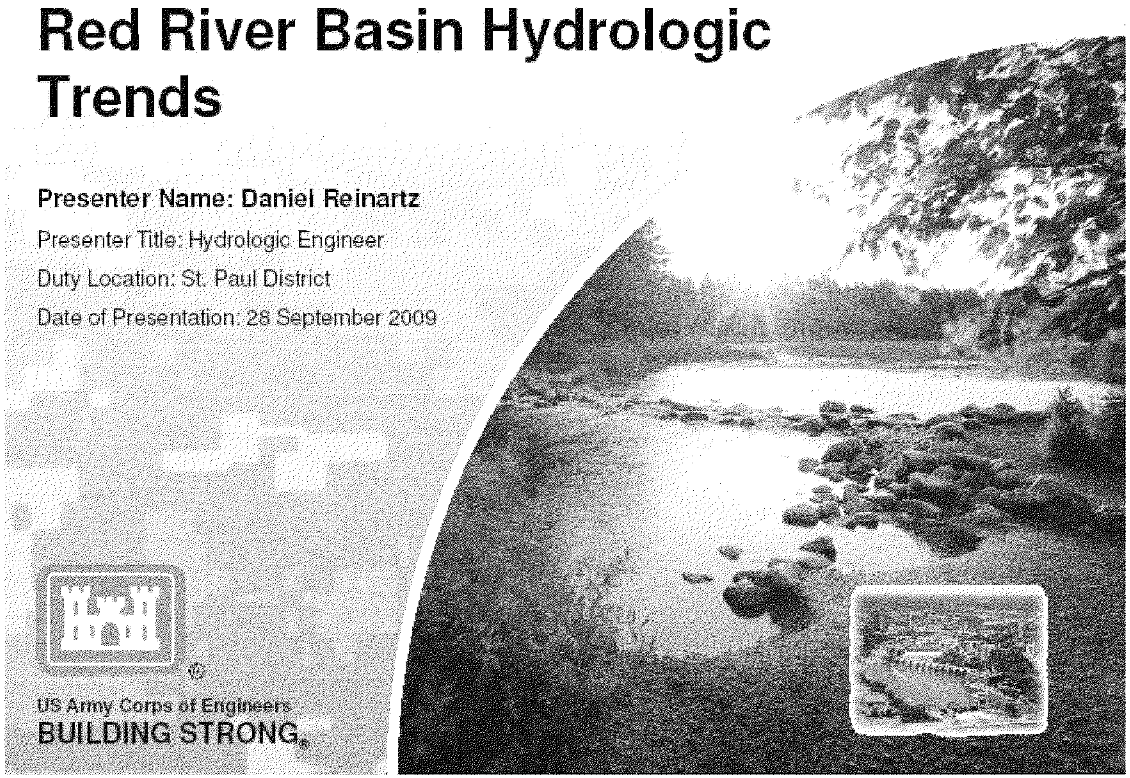
Red River Basin Hydrologic Trends
Presenter Name: Daniel Reinartz
Presenter Title: Hydrologic Engineer
Duty Location: St. Paul District
Date of Presentation: 28 September 2009
US Army Corps of Engineers
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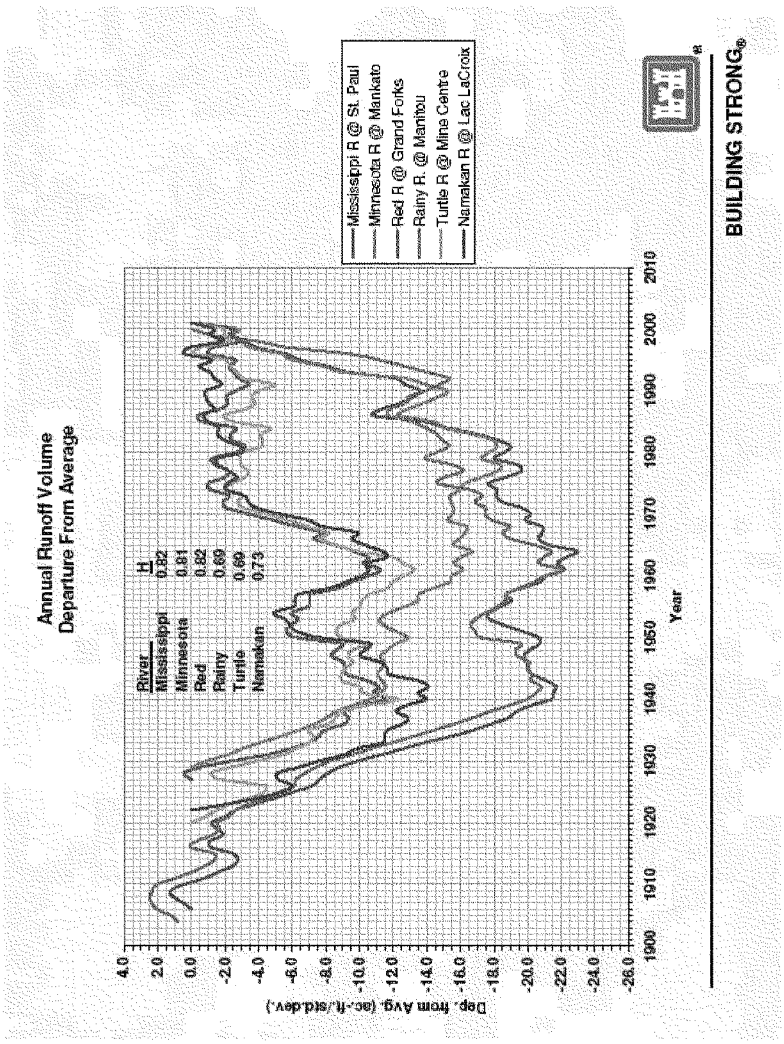

Annual Runoff Volume
Departure From Average
River H
Mississippi 0.82
Minnesota 0.81
Red 0.82
Rainy 0.69
Turtle 0.69
Namakan 0.73
Mississippi R @ St. Paul
Minnesota R @ Mankato
Red R @ Grand Forks
Rainy R. @ Manitou
Turtle R @ Mine Centre
Namakan R @ Lac LaCroix
Dep. from Avg. (ac-ft./std.dev.)
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
-12.0
-14.0
-16.0
-18.0
-20.0
-22.0
-24.0
-26.0
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year
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Hurst Coefficient

$$R / S = (n / 2)^{H}$$

Where:

R = range of cumulative departures from the mean of a time series
S = standard deviation of the series
n = length of record in years
H = the Hurst coefficient

Theoretically, H = 0.5 for a stationary process with finite memory.

For many natural time series H is in fact greater than 0.5.

Averages 0.72 with SD of 0.09

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GEOHYDROLOGICAL IMPLICATIONS OF CLIMATE

CHANGE ON WATER RESOURCE DEVELOPMENT

by

Charles W. Stockton and William R. Boggess
Laboratory of Tree-Ring Research
University of Arizona
Tucson, Arizona 85721

Prepared for

U.S. Army Coastal Engineering Research Center
Kingman Building
Fort Belvoir, Virginia 22060

May 1979

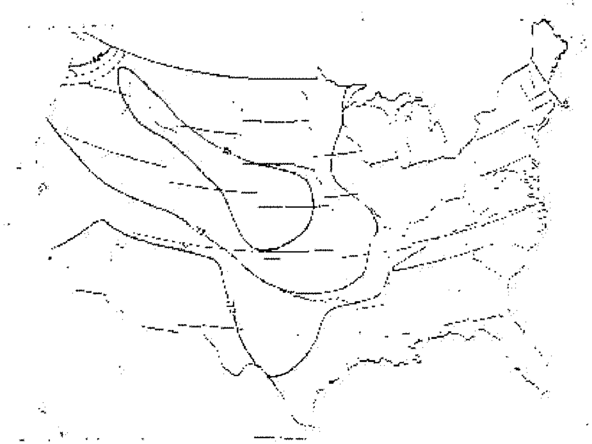
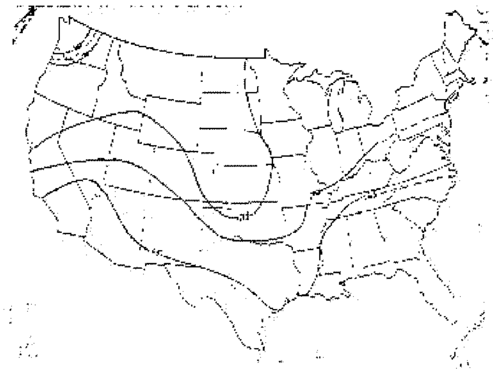


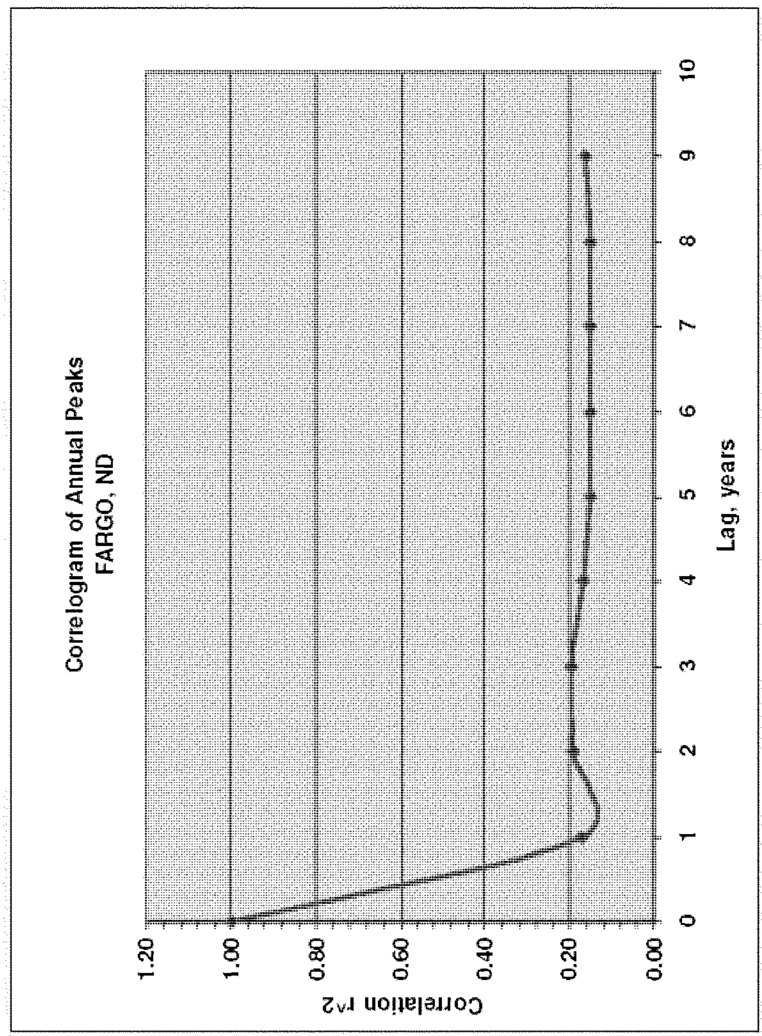
Figure 21. Maps showing regions of most persistent drought occurrences as expressed by Hurst's k. Larger values indicate greater persistence. (a) is based on 50 year increments; (b) is based on 100 year increments; period of record 1630-1962.



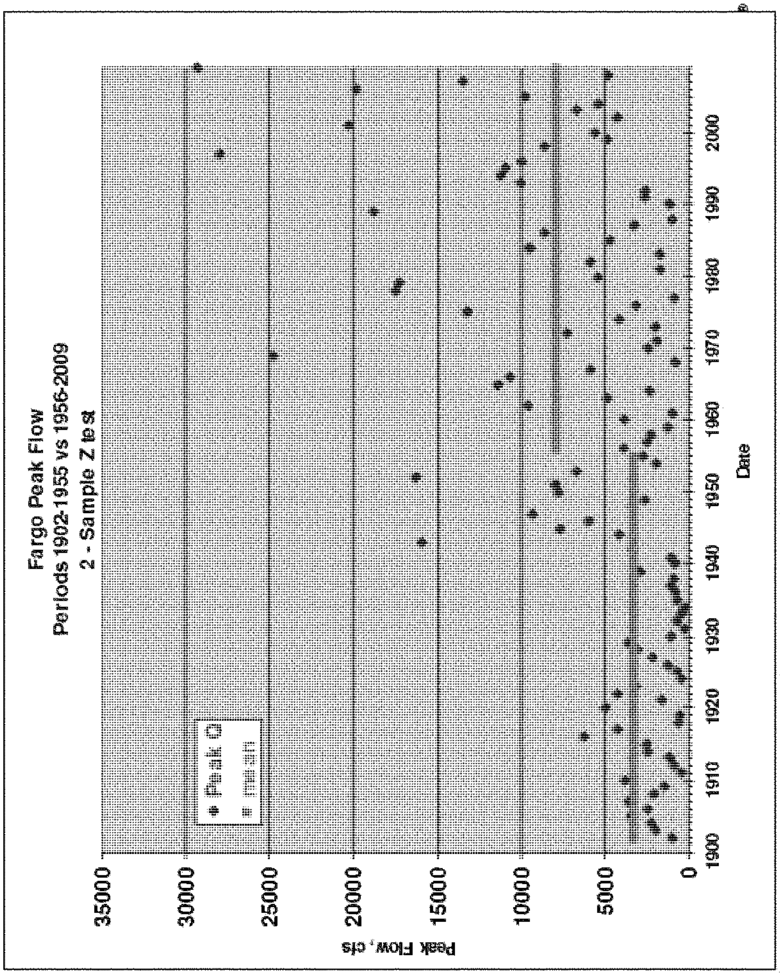
(b)

Figure 21. Maps showing regions of most persistent drought occurrences as expressed by Hurst's k. Larger values indicate greater persistence. (a) is based on 50 year increments; (b) is based on 100 year increments; period of record 1600–1962.

ING STRONG®



Correlogram of Annual Peaks
FARGO, ND
Correlation r^2
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
1
2
3
4
5
6
7
8
9
10
Lag, years



Fargo Peak Flow
Periods 1902-1955 vs 1956-2009
2 - Sample Z test
Peak Q
mean
Peak Flow, cfs
35000
30000
25000
20000
15000
10000
5000
0
Date
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000

2-Sample z Test of Mean of Peak Flows

$H_o : m_1 = m_2$

$H_a : m_1 \neq m_2$

$z = -4.38 < -1.96$

Therefore : $m_1 \neq m_2$ @ 5% Level of Significance

z-Test: Two Sample for Means		
	1902-1955	1956-2009
Mean	3225.296296	7883.019
Known Variance	11452508	45907598
Observations	54	54
Hypothesized Mean Difference	0	
z	-4.37687572	
P(Z<=z) one-tail	6.01963E-06	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	1.20393E-05	
z Critical two-tail	1.959963985	

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Variance F-Test

VAR()	11452508	49909998
COUNT()	54	54
F ratio	4.36	
Confidence	95%	
Significance	5%	
FINV()	1.58	

$H_o : s_1^2 = s_2^2$

$H_a : s_1^2 \neq s_2^2$

1.58<< 4.36

1.58 < 4.36

Therefore : $s_1^2 \neq s_2^2$ @ 5% Level of Significance

They are statistically significant at the 5 % level of significance
At 95 % confidence I reject the idea that they might be the same variance
and I accept the idea that one period is different than the other period' variance

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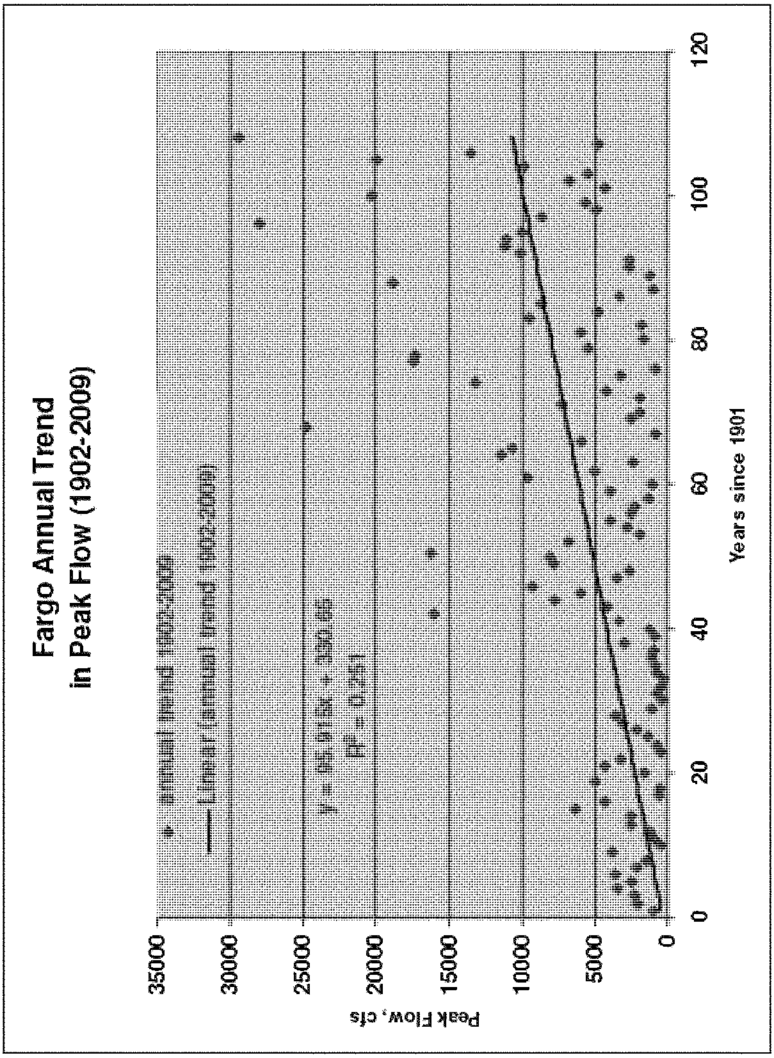
Fargo Annual Trend
in Peak Flow (1902-2009)
Peak Flow, cfs
Years since 1901
35000
30000
25000
20000
15000
10000
5000
0
20
40
60
80
100
120

Test of Regression Slope

- $Q = a + b(t_i)$
- Test slope b @ .05 level of significance
- 2-sided test of the mean
- $5.21 > 1.96$
- Therefore: slope is statistically > 0 @ .05

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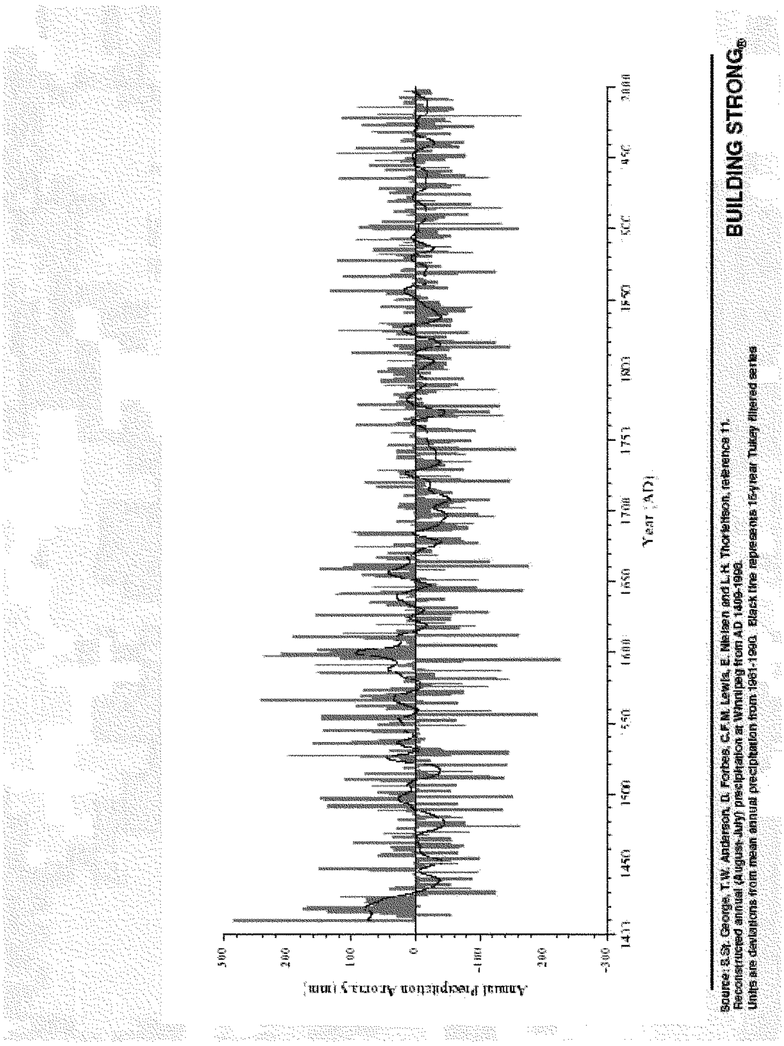

Annual Precipitation Anomaly (mm)
Year (AD)
BUILDING STRONG®
Source: S.St. George, T.W. Anderson, D. Forbes, C.F.M. Lewis, E. Nielsen and L.H. Thorleifson, reference 11.
Reconstructed annual (August-July) precipitation at Winnipeg from AD 1409-1999.
Units are deviations from mean annual precipitation from 1961-1990. Black line represents 15-year Tukey filtered series

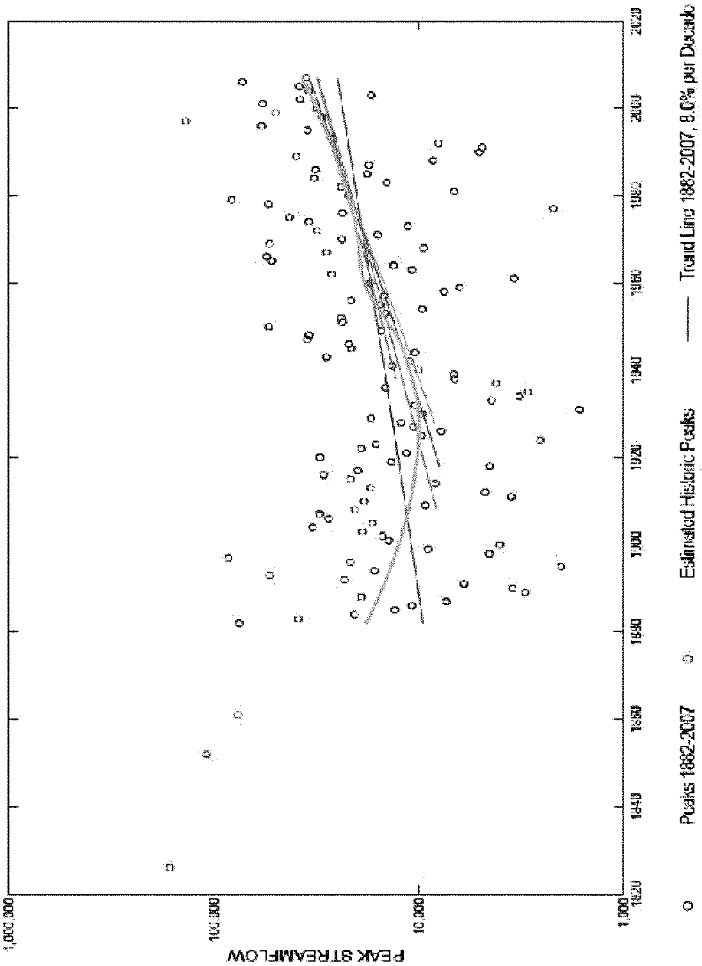


Figure 1. Trends in peak streamflow, Red River of the North at Grand Forks, North Dakota.

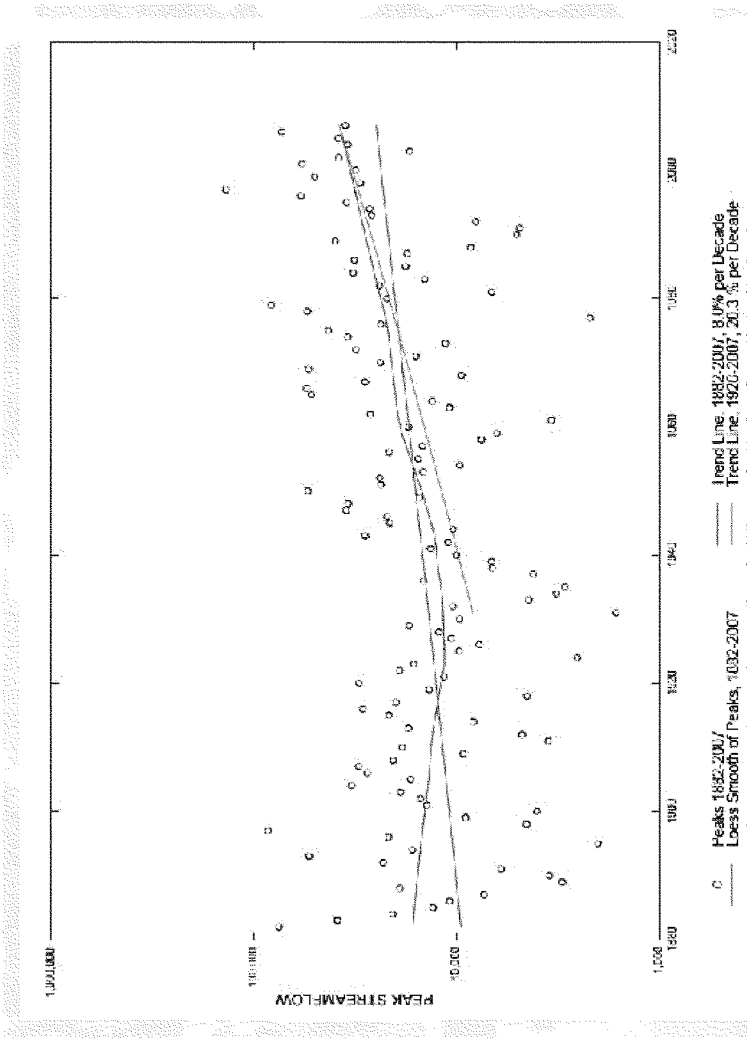


Figure 1. Trends in peak streamflow, Red River of the North at Grand Forks, North Dakota.

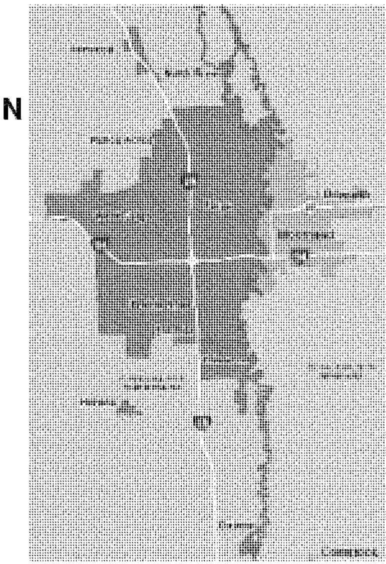

Fargo-Moorhead
Metropolitan Fea
Study
for
Expert Panel

CITY OF Fargo

CITY OF MOORHEAD MINNESOTA

STUDY AREA

- ✓ Fargo-Moorhead metropolitan & surrounding area
  - ✓ North: Harwood, ND & Kragnes, MN
  - ✓ South: Oxbow, ND
  - ✓ East: Dilworth, MN
  - ✓ West: West Fargo, ND



CITY OF Fargo

CITY OF MOORHEAD MINNESOTA

STUDY GOALS

- ✓ Develop a system to reduce regional flood risk
- ✓ Determine the Federal role in implementation
- ✓ Document findings in a Feasibility Report
- ✓ Recommend a project to Congress

CITY OF Fargo

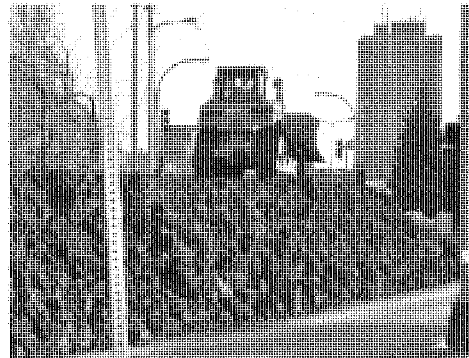
CITY OF MOORHEAD MINNESOTA

Planning Process

1. Specify problems and opportunities.
2. Inventory and forecast conditions.
3. Formulate alternative plans.
4. Evaluate effects of alternative plans.
5. Compare alternative plans.
6. Select recommended plan.

Risk

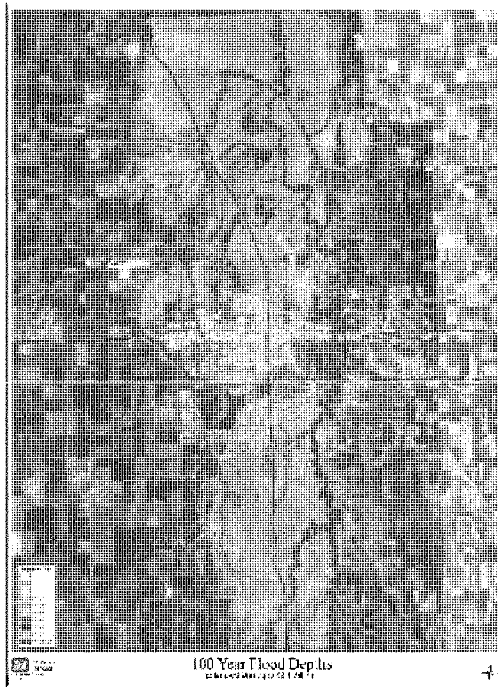
- ✓ The 2009 flood was approximately a 125 year flood event.
- ✓ Successful flood fights lead to a false sense of security.
- ✓ It would be very difficult to fight floods larger than the 2009 flood.
- ✓ Failure of emergency levees would be catastrophic.



Building of 2nd St. Levee for 2009 Fargo-Moorhead Flood

CITY OF Fargo

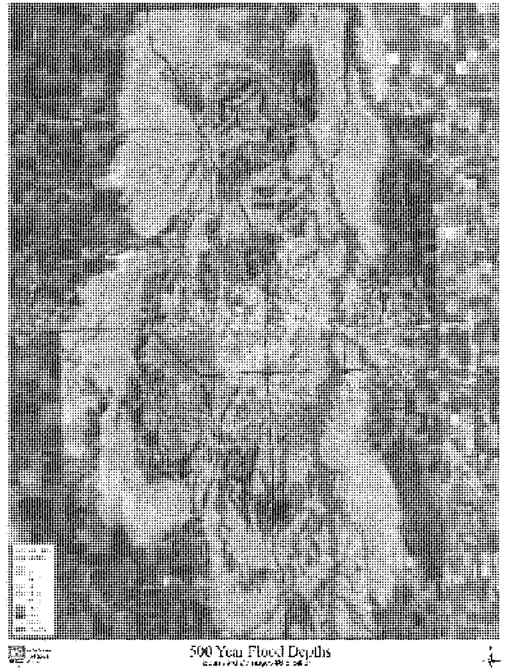
CITY OF MOORHEAD MINNESOTA



Potential depths of inundation

CITY OF Fargo

CITY OF MOORHEAD MINNESOTA



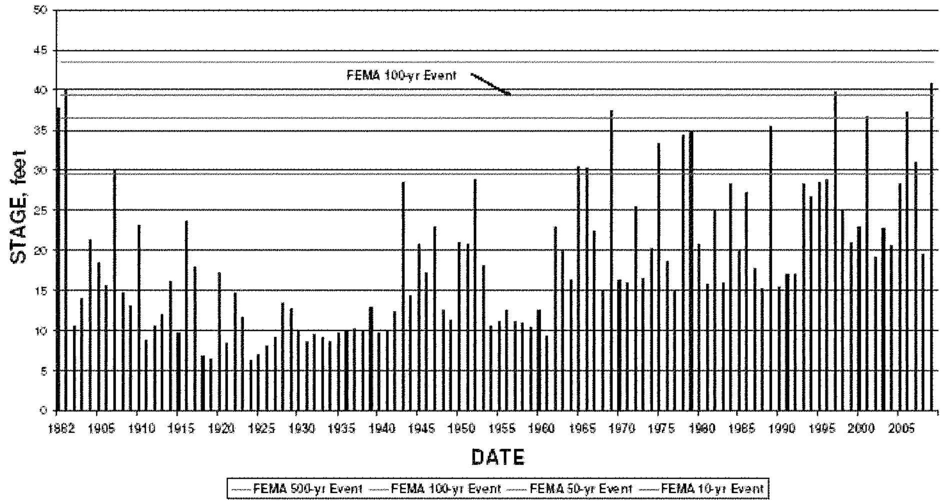
Potential Depths of Inundation

CITY OF Fargo

CITY OF MOORHEAD MINNESOTA

Annual Peak Stages

U.S.G.S Station - 05054000



✓ 2009 flood in Fargo-Moorhead was approximately a FEMA 125-year (0.8% chance) flood.

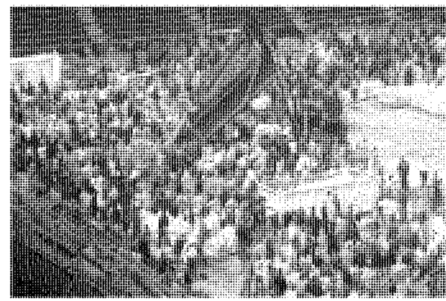
CITY OF Fargo

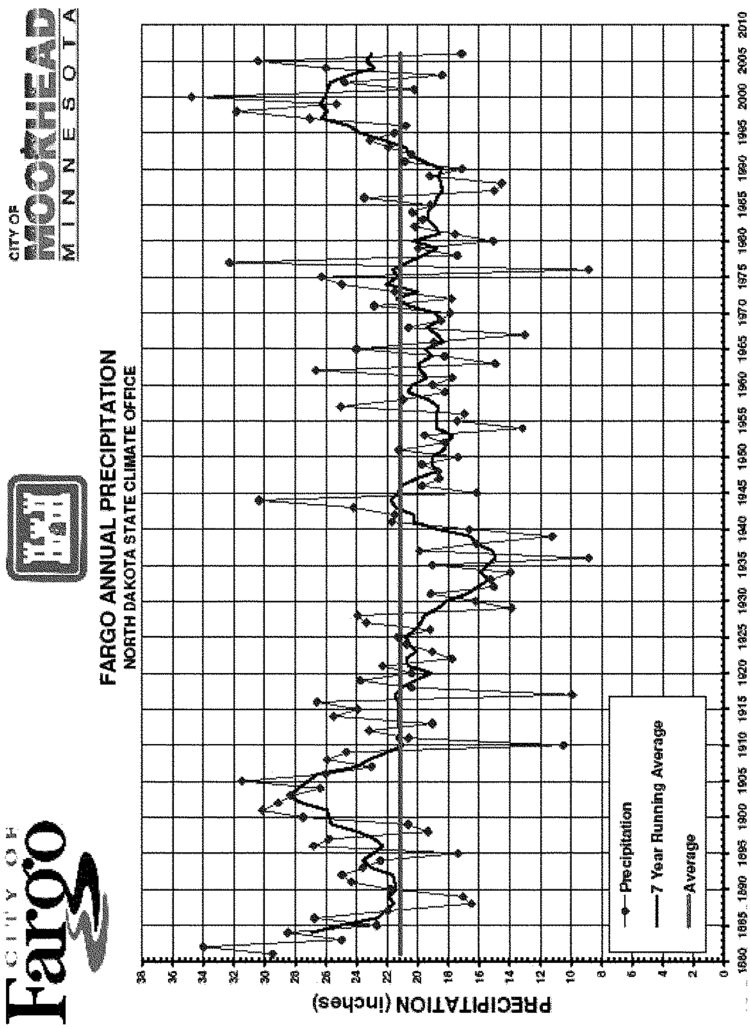
CITY OF MOORHEAD MINNESOTA

Flood Risk

During the life of a 30-year mortgage, the odds of having a Red River flood larger than the 2009 flood are about

1 in 5.



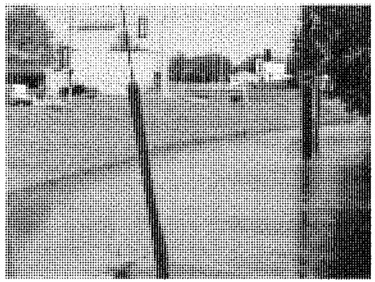

CITY OF Fargo
CITY OF MOORHEAD MINNESOTA
FARGO ANNUAL PRECIPITATION
NORTH DAKOTA STATE CLIMATE OFFICE
PRECIPITATION (inches)
Precipitation
7 Year Running Average
Average

CITY OF Fargo

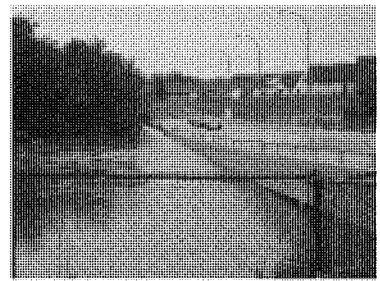
CITY OF MOORHEAD MINNESOTA

Flood Risk

- ✓ Rain events cause flooding, too:
  - ✓ 7-inch rain June 20, 2000
  - ✓ Flood insurance can help mitigate that risk.



2nd St. North, Fargo



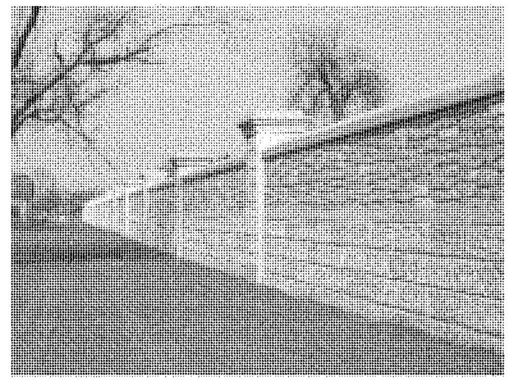
12th Ave. Toll Bridge

CITY OF Fargo

CITY OF MOORHEAD MINNESOTA

ALTERNATIVES

- Continue Emergency Measures
- Non-Structural Flood Proofing
- Flood Barriers
  - **Levees/Floodwalls**
  - **Gate Closures**
  - **Pump Stations**
- Increase Conveyance
  - **Diversion Channels**
  - **Cutoff Channels**
  - **Replacing Bridges**
- Flood Storage
  - **Part of Fargo-Moorhead Upstream Study**



Floodwall at Grand Forks

City of Fargo | City of Moorhead Minnesota

F-M METRO STUDY TIMELINE

- ✓ Sept 2009: Alternative Screening
- ✓ Jan 2010: Identify tentatively recommended plan
- ✓ Sep 2010: Finalize feasibility report
- ✓ Dec 2010: Transmit recommendation to Congress
- ✓ Jan 2011: Begin Plans and Specifications
- ✓ April 2012: Begin Construction

Attachment 6. Experts' verbatim responses

Each question, the experts' verbatim first responses, and the experts' verbatim final responses are provide here.

The experts are identified here only as A, B, C, D, E, and F.

Question 1

Is it likely that climate change will have a significant impact on the flood flow frequency curve during the life of the proposed flood risk reduction project for Fargo, ND-Moorhead, MN?

Question 1 was re-worded into a two-part question prior to soliciting the experts' final responses: A. Has historical climate change/variability been accounted for in an appropriate manner in the proposed frequency analysis? B. If climate was addressed appropriately to date, do we need to consider climate change [in this project's analysis]?

Question 2

How will the frequency curve change?

Question 2 was re-phrased slightly for the final response: Assuming we have the right frequency curve, how will that change in the next 50 years due to climate change?

Question 3

What are the practicable alternatives for accounting for the impact of the change?

Question 4

Of the alternatives available, which is best for this particular application, given the limitations imposed by the urgent need to reduce risk in Fargo/Moorhead?

Table 4. Question 1 responses

Question 1 (preliminary): Is it likely that climate change will have an impact on the flood flow frequency curve during the life of the proposed flood risk reduction project for Fargo ND-Moorhead, MN?
Question 1 (final—2 parts): A. Has historical climate change/variability been accounted for in an appropriate manner in the proposed frequency analysis? B. If climate was addressed appropriately to date, do we need to consider climate change [in this project's analysis]?

Expert	Preliminary response	Final response
A	No. If one assumes stationarity and the full period of record. As far as the application, the question of climate change influence on EAD is more to the point. Even if answered yes, when/how you apply the changed condition probably makes even [less of a] change in the economics.	A. Yes, because (assumption) climate change data set "small," however this would need [to be] checked. B. Yes, if one switches and assumes climate change data set.
B	No, climate change and its effect on flood frequency [are] on a longer time scale than the economic benefit (life of project). That being said, we are on an upward trend of having more frequent and severe floods occurring in the Red River Valley the past 30 years as compared to the entire period of record and beyond. Climate change may have a more noticeable effect with regard to flooding on time scales ranging from 50-80 years and beyond.	A. No. Using a long period of record puts too much emphasis on what has happened in the distant past > 50 years. This does not account for anthropogenic effects. B. No, because climate change and its impact has been accounted for in the flood frequency distribution to the best of our ability. Do I believe floods will become more frequent and more severe in the next 50 years? Yes.
C	If "climate change" is defined to mean a change driven by increasing greenhouse gas concentrations, I would say that it is unlikely to have a significant impact on the frequency curve. If "climate change" means a state change (like El Nino, or the Little Ice age) then it is certainly quite possible – but we don't know how to predict it. The most likely condition in the next few decades is construction of the present climate state (because of persistence in this part of the US). One more semantic point – change from the "floodflow frequency curve" does not (for me) mean the one computed over the past 100 or 125 years, but rather a frequency curve computed over the past 4 or 5 decades. I would not use the one from the past 100 or 125 years.	A. No – the analysis has ignored the fact that there has been a huge state-change in climate and flood frequency in this basin and throughout the region. B. Yes – it is likely that climate change will have a significant impact on flood frequency. However, we have no strong basis theoretical or empirical to assert the magnitude or direction of that change. But, our analysis should be done in a way that is cognizant of that uncertainty.

Question 1 (preliminary): Is it likely that climate change will have an impact on the flood flow frequency curve during the life of the proposed flood risk reduction project for Fargo ND-Moorhead, MN?
Question 1 (final—2 parts): A. Has historical climate change/variability been accounted for in an appropriate manner in the proposed frequency analysis? B. If climate was addressed appropriately to date, do we need to consider climate change [in this project's analysis]?

Expert	Preliminary response	Final response
D	Climate variability has had a significant impact on flood frequency in the Fargo-Moorhead region. It is uncertain how future natural variability will affect the flood frequency during the life of [this] project. Climate change due to global warming will likely lead to higher temperatures in the region, but its effect on precipitation is uncertain. Bottom line, yes, climate impacts flow frequency.	A. No. The method assumes there has been no climate change or variability over the record. It appears that the flood frequency curve has been significantly different in different periods. B. Yes. Climate changes over multiple time scales due to multiple reasons. These changes are uncertain. This uncertainty must be taken into account in the analysis. A single flood frequency curve may not be adequate to describe this uncertainty.
E	Alteration of temperature [illegible] mean annually as well as seasonally. Alteration of PET leading to changes in moisture accounting. System is apparently significantly dominated by snowmelt or rain on snowmelt. (Only one major river generated flood (1975)). Can't say for sure whether CC will affect flood flow frequency curve but will change flood magnitudes. Flood magnitudes would also likely change regardless of greenhouse gas forcings. Total answer floods will be influenced by climate direction of shift unknown as function of ΔT, ΔP, and separation from larger time scale climate variability. I think that greenhouse forcings will influence ΔT, ΔP.	A. No. I think there is a clear break in distribution, or at a minimum autocorrelation that affects frequency analysis (FFA). Also I think that uncertainty characterization underestimates true uncertainty. B. Yes, but not necessarily to influence FFA. Simple qualitative sensitivity analysis on projected precip and temp vs. observed. If inside variability envelope in observed record includes projections (which I think it will) then answer = No.
F	Yes, if climate change refers to natural change as a result of decadal-scale variability in ocean temperature and atmosphere pressure anomalies, this change will have a large impact on the frequency curve. If change refers to a gradual change due to greenhouse gases, it's anybody's guess if or how this will affect flood frequencies in the next 20-30 years. There is no way to tell right now how precipitation will change.	A. No, long-term climate variability has not been accounted for. The flood peaks are <u>not</u> part of a homogeneous population as assumed. B. Yes, climate and hence flood-flow frequency will likely change within the life of the project, but not substantially within the first 10-20 years.

Table 5. Question 2 responses

Question 2 (preliminary): How will the frequency curve change?
Question 2 (final): Assuming we have the right frequency curve, how will that change in the next 50 years due to climate change?

Expert	Preliminary response	Final response
A	Entire frequency curve will shift upwards especially if you re-establish "new" data set. This is contingent that a decision was made to "accept" climate change is to be "driver" from some point forward.	No change to original answer. However, it seems the "climate change data" apparently has significant influence on the current frequency curve and consideration should be given to separating out data.
B	Severe floods will become more frequent (probable) than they have been in the past. This is based on the currently accepted flow frequency curve. By how much is up for discussion.	The entire probability distribution will be shifted upward. The amount that they would be shifted upward is unknown and up for debate.
C	We have no strong scientific basis for asserting how flood frequencies will change over the coming decades. Warmer air could bring more winter precipitation but warmer air could prevent the build-up of large snowpacks which are required for the generation of large floods. We could see more frequent floods in excess of 25,000 cfs or we could see fewer floods in excess of 25,000 cfs. (I use 25,000 as a rough threshold for floods that are significant producers of economic damage.	I won't change what I said on my first answer to this question – I would add some clarification. I think that in future decades the chance of floods similar to those typical of the 1920s, 1930s, and most decades before about 1960 are relatively small. Flooding behavior more like that which has happened since 1960 is much more likely in the future decades. The very unusual behavior of the Red River should cause us to consider unusual approaches to the problem (like Markov shifts, truncating the record, putting much more uncertainty into our analysis, or selecting other types of flood frequency curves). Assuming that our hundred year (or 125 year) history is a good sample of the likely future or that a stationary model is appropriate would be irresponsible.
D	The change in the flood frequency curve is uncertain. It is likely that more recent climate conditions will persist for a while, so the last fifty years may be more representative of the next decade. However, it is not currently predictable if and when a shift to drier conditions would occur. It is also likely that temperatures will warm. This may impact when and how fast snow melts and could increase evaporation. Rather than rely on a predication of changes for a future flood frequency curve, it is better to accept greater uncertainty in its estimate.	How the flood frequency curve will change in the future is uncertain. It is important to take this uncertainty into account in the decision process. One possible approach is to evaluate how sensitive the decision is to the choice of freq distribution. Two possible distributions to use: 1) Entire period of record. 2) Use data since 1960. It may be better to choose an alternative that does well for both scenarios, rather than try to maximize NED for one or the other distribution.

<table>
<tr><th colspan="3">Question 2 (preliminary): How will the frequency curve change?
Question 2 (final): Assuming we have the right frequency curve, how will that change in the next 50 years due to climate change?</th></tr>
<tr><th>Expert</th><th>Preliminary response</th><th>Final response</th></tr>
<tr><td>E</td><td>(1) I would think you would want to create at a minimum <u>two</u> FFAs for at a minimum <u>two</u> observed climate states. Then you could use a transition probability matrix to consider how to get from one to the other. Most straightforward approach. I do not think that skew should be used to go too negative.

For example, [expert drew two images: one showed a curve with x-axis "1900-1970" and the other showed a curve with x-axis "1970-2009."]


1900 1970 1970 2009

Create transition probability matrix from St. George precipitation analysis from 1600-200?

Prob: Wet → Wet | Prob: Wet → Dry
Prob: Dry → Wet | Prob: Dry → Dry

This would fit well within Monte Carlo analysis through time to get at annualized damages.

(2) For future climate change if you wanted to consider projection information I think you could use this to influence prob matrix if criteria from answer to 1.B was met. I think that uncertainty bounds on FFA regardless of approach will go up.</td><td>Same answer as preliminary answer with the following additions/clarifications.

For two FFAS

~1900-1970 – expect FFA ↓ over current

~1970-2009 – expect FFA ↑ over current

If all probabilities in matrix are equal then end result is same as now. If wet →wet prob > then wet →dry prob then because we are in a wet period to start overall FFA will also go ↑. Again though uncertainty of new FFA will go up and in my opinion needs to.</td></tr>
<tr><td>F</td><td>There will be a much higher frequency of floods in the 20-40 thousand cfs range and a much lower frequency of floods less than 10,000 cfs in the next few decades, compared to the frequencies shown in Dan's [Reinartz] curve. A flood similar to 2009 has a much higher chance than 1% per year of occurring during the next 20 years.</td><td>I'll stick with my preliminary answer. It is generally accurate, in my opinion.</td></tr>
</table>

Table 6. Question 3 responses

Question 3 (preliminary and final): What are the practicable alternatives for accounting for the impact of the change?

Expert	Preliminary response	Final response
A	Alternative 1 – Adopt "mixed population" concept and generate "climate change" frequency curve using last 30 yrs? of data. Determine appropriate out year when that curve should apply e.g., year 15, 20, etc., Use equivalent annual damage analysis in FDA using existing frequency curve at year zero and "climate change" frequency curve at appropriate out year using shortened period of record which results in large uncertainty. Alternative 2 – Using similar concept in Alt 1 only develop composite frequency curve from the two curves and apply composite curve over 50 yr life cycle. Alternative 3 – Assume there will be a 50-year wet period and use 'climate change' curve for plan formulation. Out year determination – Perform sensitivity as to when increase in flows (based on trend) will impact EAD by X%. At that point, apply "climate change" curve.	Alternative 1 – This alternative was offered strictly on the current capability of FDA, i.e., using current conditions and most likely future condition (1 only). Alternative 2 – Can be realized with 2 FDA runs using current frequency curve [and] a "wet period" frequency curve and apply year to year weightings as discussed within the group to determine "combined" EAD outside of FDA.
B	A practicable alternative for accounting for the impact of climate change could be to shorten the period of record and only use the last 30 years of observed annual maximum peaks. This would help place a greater emphasis on the trend that floods in the Red River specifically @ Fargo/Moor. have been increasing in frequency and magnitude. This approach would line up nicely with the way climate statistics are calculated. The question with this approach would be how often would this be re-evaluated and updated? Climate statistics are re-calculated every 10 years. This seems to be a bit too infrequent. An update cycle of 5 years seems to be reasonable. This approach seems logical given the short turn around that is needed with regard to this project. The approach of having two flood frequency curves for wet and dry periods and transitioning between the two seems to be more complex and the benefit or advantage using this approach over shortening the analytical period or record seems unclear.	(1) Shorten the period of record that is analyzed using only the latest portion of the record. The period to use could be to use the "wet" portion of the record, or to use only the latter half, etc. Statistics could be used to determine what should be considered a "wet" period of record. (2) The period of record could be considered a mixed population and could be divided into a wet period and a dry period of record. Statistics could be used to determine this; otherwise the period of record could be divided at the mid point to develop two frequency functions. These two functions could then be combined and be weighted equally or more weight could be assigned to the "wetter" period. Suggested weights that have been proposed are between .2 and .8 for dry and wet to .5 for both wet and dry periods.

Question 3 (preliminary and final): What are the practicable alternatives for accounting for the impact of the change?

Expert	Preliminary response	Final response
C	View this as a mixed population of floods. The data are clear, the early decades of the twentieth century are totally unlike the past five or so decades. Fitting a single probability distribution to both samples makes no sense. I would divide the record into two parts 1902-1959 and 1960–2009 and call them the "old" and "new" populations. You can do sensitivity analysis at the dividing line but I'm already pretty sure that it doesn't make too much difference. The dividing line shouldn't be set to "pick up" one particular large flood in the "new" set. Then I would estimate two separate flood frequency distributions. (I'm sure the 100-yr flood in the 'new' will be about 2.5X the 100-yr in the "old.") Then I would construct a mixed population flood frequency from the two distributions. I would run sensitivity analysis, varying the probabilities of the "old" from 0 to 0.537 (0.537 is the fraction of the whole data set in the "old.") I would select a best judgment estimate of this probability somewhere around 0.2. My reasons for this low number are three-fold: 1) persistence of wet conditions in the region based on historical data from tree rings, Grand Forks Q, Winnipeg Q, the research of Knox...2) the potential that greenhouse forcing might favor a tendency to larger floods, 3) engineering judgment calling for high levels of projection against "surprise" in the very vulnerable, very flat, and very hard to understand environment.	A clarification of what I said previously- the expert panel should determine the break point in the record and the subjective probability of being in each of the two states (old and new) explaining the considerations that went into setting it. We were asked to serve as experts on this issue and it is appropriate that we decide and not just "kick the can down the road" for someone else to do it. Given that it is subjective I think it is problematic to have the Corps do it – they asked for our help because credibility and objectivity are important. Having stakeholders do it is a terrible idea/ they will have plenty of opportunity to weigh in on designs and preferred alternatives; this is the technical part of the process and it needs to be handled by the technical experts brought in by the Corps.

Question 3 (preliminary and final): What are the practicable alternatives for accounting for the impact of the change?

Expert	Preliminary response	Final response
D	There is large uncertainty in the flood frequency curve. This uncertainty should be included in the flood damage economic analysis. Uncertainty is more than uncertainty in mean and variance. Include skew uncertainty. Use a smaller effective sample size. Consider doing a scenario analysis with two different probability distributions: 1) Entire period of record. 2) Record since 1960 (or so). Evaluate how choice of probability distribution affects different alternatives. It may be better to choose an alternative that performs reasonably well for both scenarios, rather than maximize NED for one or the other distribution. Both approaches are consistent with current USACE planning guidelines. Uncertainty should be included in economic analysis. P&G says a sensitivity analysis should be done to show effects of uncertainty on decision. The alternative that maximized NED does not have to be the recommended plan.	No major change from preliminary except a mixed distribution could be considered as a third distribution in the scenario analysis. 1) POR distribution 2) Mixed distribution 3) Wet period distribution A long memory process indicated a smaller effective sample size; Hurst coefficient > 0.5.

Question 3 (preliminary and final): What are the practicable alternatives for accounting for the impact of the change?

Expert	Preliminary response	Final response
E	Alternatives: [Presented in the text below and the table on the following page.] 1) Account for autocorrelation which will reduce your period of record and increase your uncertainty estimate. Reduction of period of record can be done (a) qualitatively →essentially no time (b) quantitatively →medium effort. 2) Two state system with period of record derived from early 20th century to late 20th century-early 21st century. Definitions of change can be done (a) qualitatively (b) quantitatively → test statistics of homogeneity. Use transition probabilities either (1) from short period of observed record, or (2) from rainfall analysis of St. George et al. Use the Monte Carlo framework to combine into a simulated flood frequency/damage curve. End result of any path will be increase in uncertainty. 3) Truncate record to consider only recent period (don't like this alternative) (a) qualitatively (b) quantitatively 4) Continue with current curve (don't like this). For all cases I think it prudent to spend 1-2 days to look at projections and show that rain / temp projections for next 30 years within envelope of observed variability.	I would like to keep my answer from the preliminary answer sheet. From the discussion period I think that an addition of using two separate analyses in a sensitivity sense through the economics portion (a la [another expert]) is a viable alternative. I think also an outcome from the discussion is that some of the details contained within proposals are important.

Question 3 (preliminary and final): What are the practicable alternatives for accounting for the impact of the change?

Expert	Preliminary response			Final response
	Alt	Level of effort (1-5)	Rating of information (relative to each other)	
E (cont)	1a –auto corr /qual	2 - requires judgment	3	
	1b –auto corr /quant	3 - some to statistically account for autocorr; could be a little tricky	3+	
	2a1 -2 / qual / obs	3 - easiest of 2 state approach requires judgment and treatment of obs	3+	
	2a2 – 2 / qual / rain	4 - must stat treat rain could be tricky	4	
	2b1 – 2 / quant / obs	4 - quant determine break point	3+	
	2b2 – 2 / quant / rain	5 - quant determine break point must stat treat rain	4 ~ 4+	
	3a – truncate / qual	1 - little	2	
	3b – truncate / quant	2 - little but must do test stat	2	
	4 – cont. with current	1 - no effort	1	

Question 3 (preliminary and final): What are the practicable alternatives for accounting for the impact of the change?

<table>
<tr><th>Expert</th><th>Preliminary response</th><th>Final response</th></tr>
<tr><td>F</td><td>There are 3 practicable alternatives:

(1) Use the regulated period of record (1942-2009) to develop all the frequency curves. This would somewhat underestimate the most recent (1980-2009) risk and overestimate the prior (1942-79) risk, but on average this may be a good approach for estimating "average" risk over the life of the project.

(2) Develop two frequency curves – one for "wet" conditions and one for "normal" conditions, and estimate transition probabilities (wet→wet, wet→dry, etc.) for future years. There are two problems with this – what to use for future historical "wet" and "normal" periods (1960-2009 (wet) vs. 1901-1959 (normal) is one of the several possibilities) and how to estimate the transition probabilities. If we can decide on answers to these problems, this might be the best approach.

(3) Develop a stochastic water-balance model for generating annual flows on the basis of monthly precipitation, evaporation, and basin storage. Use the annual flows to condition the flood frequency curve (i.e., if annual flows 50% above long-term average then flood flows 50% above average). This may be the hardest to accomplish of the 3 approaches in a short period of time.</td><td>I think there are two reasonable alternatives:

1) Use 1942–2009 as the representative time period for developing all discharge-frequency curves. The added uncertainty in using a shorter time period is a good thing, especially in that it will increase the upper confidence curve.

2) Use a weighting scheme to "morph" from the "wet" frequency curve to the full-record curve something like this:
<table>
<tr><th>Year</th><th>Mixed pop probabilities for 1960–2009</th><th>Full record (current curves in Dan's report)</th><td rowspan="8">NOTE: We may want to tweak their probability or do a sensitivity analysis</td></tr>
<tr><td>2010</td><td>1</td><td>0</td></tr>
<tr><td>2011</td><td>.95</td><td>.05</td></tr>
<tr><td>2012</td><td>.90</td><td>.10</td></tr>
<tr><td>2020</td><td>.50</td><td>.50</td></tr>
<tr><td>2021</td><td>.45</td><td>.55</td></tr>
<tr><td>2030</td><td>0</td><td>1</td></tr>
<tr><td>2031</td><td>0</td><td>1</td></tr>
</table>
Develop uncertainty curves for mixed populations using established methods.</td></tr>
</table>

Table 7. Question 4 responses

Question 4 (preliminary and final): Of the alternatives available, which is best for this particular application, given the limitations imposed by the urgent need to reduce risk in Fargo/Moorhead?

Expert	Preliminary response	Final response
A	Alternative 3 – mixed population by using current frequency curve and a "wet period" frequency curve. Make separate FDA runs. Prepare spreadsheet that combines weighted EADs incrementally (every 1 yr, every 5 yrs, etc.) to include combined uncertainties for generation of distribution about the EAD.	Retain original suggestion. This method allows for evaluation of EAD for full 50-year period using one weighting or multiple increments with different weightings. By running separate FDA runs with each frequency curve, each result will include/retain uncertainty of each population (period of record either actual or equivalent). I would like to discuss with others how the individual uncertainties will play out in developing distribution of EAD and performances. Period of data split—defer to the appropriate test for determining the split.
B	Given the limits imposed by the urgent need to reduce risk in Fargo/Moorhead, the alternative that seems appropriate to use is to treat the entire period of record as a mixed population. The period of record could be divided into a wet period and a dry period. Statistical analysis should be used to determine the break point between the two populations. Once divided, two separate flow frequency functions should be created and weighted appropriately before being combined. Since it is apparent that the Fargo/Moorhead area has been in a wet cycle and future climate projects are calling for this pattern to persist, emphasis should be placed on the "wet" frequency curve with a weight of 0.8 associated with that function. The "dry" frequency function should have a lesser weight of 0.2. This scheme emphasized that the wet years are more appropriate for the foreseeable future, while still hedging that there is still a chance that the climate pattern could become drier the next 30-50 years.	In addition to what was previously written: Assuming skew coefficients are very similar, an average with appropriate rounding of the two should be used. This should be very inconsequential since preliminary analysis shows the skew for both populations were nearly identical. If the skew calculations of the two populations vary significantly, study participants should make the appropriate decision using accepted methods with regard to skew calculations. No recommendation for how uncertainty should be calculated or estimated will be made. However, study participants should consider this problem and make the appropriate decision using accepted techniques with regard to uncertainty analysis.

Question 4 (preliminary and final): Of the alternatives available, which is best for this particular application, given the limitations imposed by the urgent need to reduce risk in Fargo/Moorhead?

Expert	Preliminary response	Final response
C	I would use approach #3, mixed population. I would break the record into 2 periods 1902-1941 and 1942-2009. I select this break point based on a recent paper by Villarini, Serinaldi, Smith, and Krajewski (Water Resources Research, Vol. 45, W08417, 2009). They did a change point analysis, for change in the mean based on the Pettitt test ($\alpha = 0.05$) and the Fargo record shows a significant step change at 1942. I would do LPIII analysis on each period, but to estimate skew I would take all the data values (the log discharges) and subtract the group mean, divide by the group standard deviation from the appropriate group, and then compute a skewness on all 108 values—I would suggest using this combined skew rather than 2 different ones—they are too small a sample size to do them separately. I would set a subjective estimate of the marginal probabilities of being in the wet (later) population at 0.8 and a probability of the dry (earlier) population at 0.2. However I would, for sensitivity analysis, try setting the probability of the dry population at 0.37 (which is its proportion in the data set) and also at zero (meaning we think we will not be going back to the dry state). I would have the basis for setting the probability at 0.2 be stated (reasons given in my answer to question 3), fully admitting that it is subjective and was set by the expert panel, mindful of the increased hydrologic history of the basin, greenhouse forcing concerns, and engineer's judgment.	The only thing I would add to my previous answer is the way that uncertainty is handled. Given the mixed population model I would be inclined to state the equivalent years of record for both populations as the number of years in the shorter of the two periods—in order to be conservative on this issue. The simulation in FDA should be run twice—once with each distribution and then combined with the appropriate weight based on the probabilities. My choice of weights (probabilities) would be 0.2 for the dry and 0.8 for the wet.

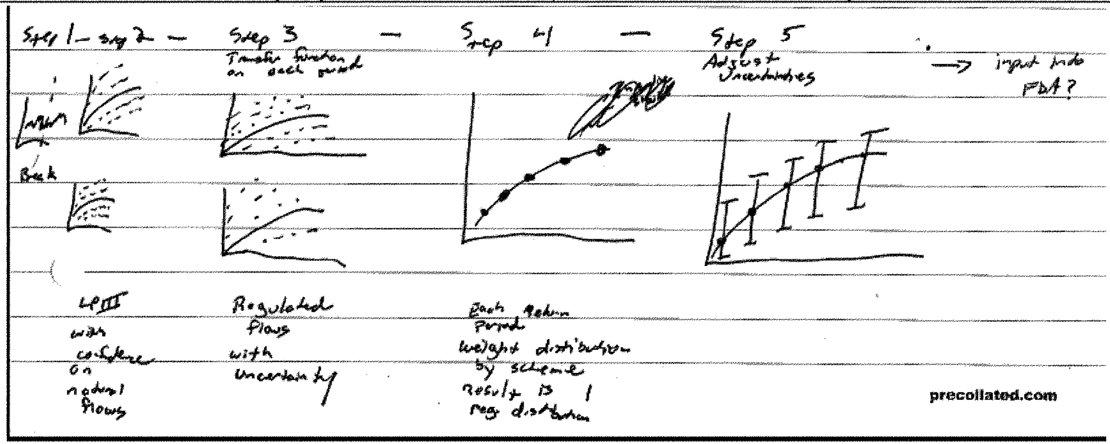
Question 4 (preliminary and final): Of the alternatives available, which is best for this particular application, given the limitations imposed by the urgent need to reduce risk in Fargo/Moorhead?

Expert	Preliminary response	Final response
D	1) Initially, current distribution based on period of record should be used, but the economic analysis should include all sources of uncertainty, including effects of long-memory on effective sample size. 2) Economic damage analysis should be done for other possible probability distributions, including a distribution based on the wet period and a mixed distribution. 3) Planners and designers should think beyond optimizing a design for maximum NED. They must consider the consequences for the design if their assumptions about the flood frequency distribution are wrong. Public safety impacts should be considered in addition to economic analysis. For example, more uncertainty and a wetter distribution would imply a larger design would provide more economic benefits. This would be counter productive if it encourages more development in vulnerable areas. Planner, designers, and the public must know that the flood frequency distribution is uncertain, and what are the potential consequences of their decision under different scenarios.	Recommend using a mixed distribution with three assumptions on weighting wet and dry periods: (1) Using same weights as occurring in period of record (2) Intermediate weight (3) Weighting assuming only the recent wet period will occur Economic damage analysis should be done for each distribution. I would also include the current distribution assuming stationarity be used for comparison. Recommend calculating the skew individually for each part of the mixed distribution. I think the most important action to take is to communicate the uncertainty in the flood frequency distribution to the planners and public, and to try to choose an alternative that does well even if we have mischaracterized the distribution. Then a selected alternative should do reasonably well for each of the three distributions.

Question 4 (preliminary and final): Of the alternatives available, which is best for this particular application, given the limitations imposed by the urgent need to reduce risk in Fargo/Moorhead?

Expert	Preliminary response	Final response
E	My first opinion is that two frequency curves should be considered from the observed record. The definition of these two periods can be done subjectively although if someone is available who has experience with a homogeneity statistic this is preferred. If subjectively I think that care should be given and a couple years considered to see how different the results are. Given the constraints these two curves can be combined subjectively, however I think that at least some attempt should be made to establish a quantitative basis using the historic rain record and potential projections of change. I think that the final result should be more weighted on the wet period but should include some probability for the dry period not to exceed 0.5. Meaning that final curve should have magnitudes greater than what has been presented to date. Further, the end result should have confidence intervals that are wider than those presented. If weighting done quantitatively and not considered research, ideal approach is exploring Markov chain, or 600-yr rain record, or probability percentage of dry period being another 50 years. If looking for a subjective prob., I would propose wet = 0.75 and dry = 0.25, although reasonable response could be anywhere 0.5-0.5.	Two distribution functions. Definition of break should best be determined using statistical test of homogeneity or peer-reviewed published value if available. Both sides should be considered within LPIII framework. Late 1800s floods can be used in either record at discretion of project engineer. This should be performed on "natural flows" and will need to be re-regulated later. Would prefer to see a function of weighting going from 1-wet to 0-dry over the course of the 50-year period if some justification can be determined through exploration of the 600-year rainfall record. If not, a subjective combination can be used, [which] would consider 0.75 wet and 0.25 dry. [Illegible sentence—appears to be something like—a transfer function re regulation is done should be performed on LPIII uncertainties as well as mean estimates.] The result is estimates of flows as well as uncertainties which should be adjusted upwards, i.e., higher uncertainty before entering economic analysis. This most likely will need to be subjective and 25% increase is a reasonable estimate. Step 1: Determine break in period of record. Step 2: LPIII with confidence on natural flows. Step 3: Transfer function on each period→ regulated flows with uncertainty. Step 4: Each return period weight distribution by scheme result is regulated distribution. Step 5: Adjust uncertainties. Input into FDA? Sketches included at the bottom of this expert's final response are presented in the figure below.

Question 4 (preliminary and final): Of the alternatives available, which is best for this particular application, given the limitations imposed by the urgent need to reduce risk in Fargo/Moorhead?

Expert	Preliminary response	Final response
E, final response cont.		

Question 4 (preliminary and final): Of the alternatives available, which is best for this particular application, given the limitations imposed by the urgent need to reduce risk in Fargo/Moorhead?

<table>
<tr><th>Expert</th><th>Preliminary response</th><th>Final response</th></tr>
<tr><td>F</td><td>Best alternative
1) Use 2 frequency curves for two populations:
curve 1 – 1960 to 2009
curve 2 – whole period of record
2) Compute frequency curve for each future year by mixing these two populations in specified probabilities. These probabilities should start with 1 for curve 1 and 0 for curve 2 and gradually change to 0 for curve 1 and 1 for curve 2. The actual mix might look something like this:
<table>
<tr><th rowspan="2">Year</th><th colspan="2">Probability for</th></tr>
<tr><th>Curve 1</th><th>Curve 2</th></tr>
<tr><td>2010</td><td>1</td><td>0</td></tr>
<tr><td>2011</td><td>1</td><td>0</td></tr>
<tr><td>2012</td><td>1</td><td>0</td></tr>
<tr><td>2013</td><td>.95</td><td>0</td></tr>
<tr><td>2013</td><td>.90</td><td>0</td></tr>
<tr><td>2022</td><td>.5</td><td>.5</td></tr>
<tr><td>2023</td><td>.45</td><td>.55</td></tr>
<tr><td>2032</td><td>0</td><td>1</td></tr>
</table>
3) Do sensitivity analysis using <u>just</u> curve 1 (wet) for the entire future 50 year period. This would acknowledge that the current high flood risk is a consequence of "climate change" and is likely to continue (or get worse) over the next 50 years.</td><td>Use a mixed population model, with one population being 1942-2009 ("wet") and one population being 1901-1941 ("dry"). Do not include historical floods. Start with a probability = 1 for "wet" in 2010, then decrease linearly to probability = 0.5 in 2060 (end of project). I will need to do some analysis to see how to compute the uncertainty associated with the mixed population model for each future year. I will forward that analysis to you asap. It should be relatively straightforward, but I need to do a little more research.</td></tr>
</table>

Appendix A-1c
Hydrology

Fargo-Moorhead Metropolitan Area Flood Risk Management

Supplemental Draft Feasibility Report and Environmental Impact Statement

April 2011

US Army Corps of Engineers ®

Prepared by:
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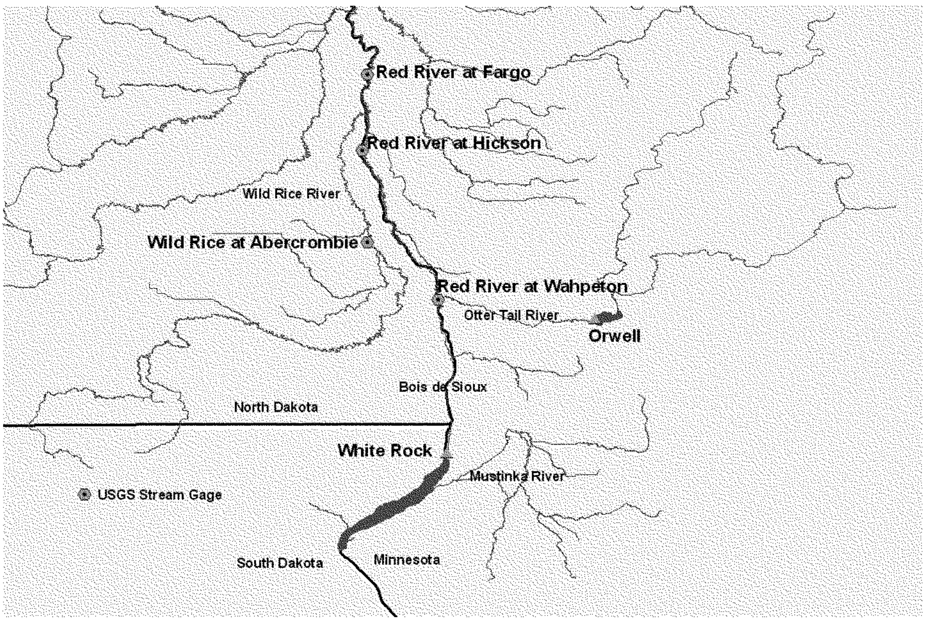
US Army Corps of Engineers
Hydrologic Engineering Center

February 2010

The use of Synthetic Floods for Defining the Regulated Flow Frequency Curve for the Red River at Fargo



Prepared By:
Hydrologic Engineering Center

Prepared For:
St. Paul District
US Army Corps of Engineers

List of Figures

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Introduction

The St. Paul District contacted HEC requesting help on updating the existing regulated peak flow frequency curve for the Red River at Fargo. This request was initiated as a response to an expert panel that concluded the Red River peak stream flows exhibited non-stationarity in the form of two flow regimes, a wet period and a dry period, and that this result should be incorporated in the development of the regulated peak flow frequency curve at Fargo. Separate flow frequency curves were developed for the wet period and the dry period, and then those frequency curves were combined to reflect estimates of the likelihood of experiencing either the wet or dry flow regime in future years. For comparison purposes, an additional analysis that incorporated the full period of record was included. Therefore, regulated peak flow frequency curves were developed for a wet period, dry period, combinations of wet and dry periods (possible future scenarios), and the full period of record.

To capture regulation from upstream reservoirs, the peak flow frequency curve was developed by graphically fitting a frequency curve to both the observed peak flow record and synthetic flood events, with the synthetic floods used to define the upper end of the frequency curve. The regulated peak flow frequency curve was developed for two scenarios. For scenario 1 the flow record was divided into two segments, a "dry" and a "wet" period, based on a test to determine the break point providing the strongest statistical evidence of separate homogeneous data sets. The resulting break point of 1941 defined the dry period with flows from water years 1902 through 1941 (40 years of record) and the wet period with flows from 1942 through 2009 (68 years of record). Separate peak flow frequency curves (and synthetic floods) were determined for both wet and dry periods and then combined for possible future conditions. For scenario 2, the entire flow record was analyzed to develop the peak flow frequency curve; water years 1902 through 2009 plus historical events from 1882 and 1897 (128 years of record).

A map of the study area is shown in Figure 1. The Red River begins at the confluence of the Otter Tail and Bois de Sioux rivers and flows north to Fargo. Two reservoirs regulate flows upstream of Fargo. Orwell dam went into operation in 1953 and White Rock dam went into operation in 1942. There are four USGS gages in the study area, three gages are located on the Red River and one is located on the Wild Rice River. The following steps provide a general overview of the process followed to develop the regulated peak flow frequency curve using observed data and synthetic floods to define the upper end of the curve. More detail is provided in the follow sections.

1) Determine break point between wet and dry periods
2) Develop the unregulated volume-duration frequency curves, 1, 3, 7, 15 and 30-days, for the Red River at Fargo. Volume-duration frequency curves were developed for the wet, dry, and full period of record.
3) Develop synthetic flood hydrographs that reproduce the 10, 50, 1, 0.5, and 0.2-percent flows on the unregulated volume-duration frequency curves.
4) Route the synthetic flood hydrographs through a reservoir model, HEC-5, to compute regulated flows downstream of the reservoirs at Hickson.

5) Route the synthetic flood hydrographs from Hickson to Fargo using an HEC-RAS model.
6) Use results from the synthetic flood events and observed data to develop the regulated peak flow frequency curve for the Red River at Fargo.
7) Combine wet period and dry period frequency curves with defined likelihoods

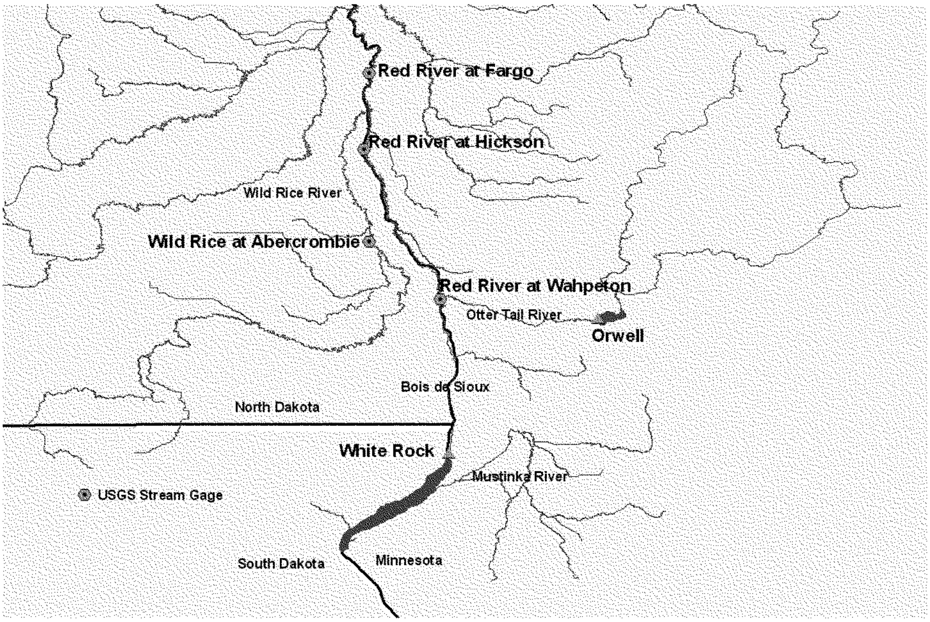


Figure 1. Red River above Fargo.

Determine break point between dry and wet periods

Figure 2 displays the record of unregulated annual peak flows on the Red River of the North at Fargo. There was a period of smaller annual peak flows in the early part of the 20th century. While the gaged record might suggest an upward trend, the large events that occurred in 1882 and 1897 (shown in the figure as estimates, but not used in the analysis) suggest instead that a cycle between wet and dry periods has been experienced in the basin. Tree-ring records of the Red River basin further support a cycle rather than a trend, showing even larger events in earlier centuries. The assumption in developing a frequency curve for a dry period and another for a wet period is that the period of each flow regime forms a homogeneous data set, and that the regime has switched at various times in the historical record. Since there is no hydrologic explanation to suggest a difference in flow regime, the EOE panel suggested seeking statistical evidence of a difference between wet and dry data sets using the Pettitt test.

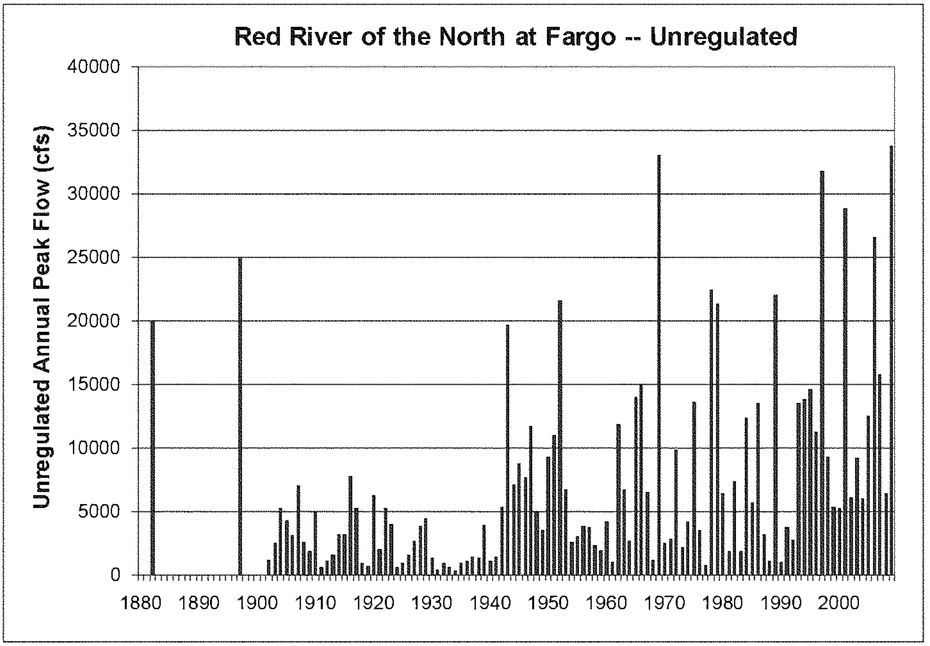


Figure 2. Unregulated annual peak flows at Fargo.

The Pettitt test is a determination of the best break point to divide a continuous data set into separate portions. The procedure involves performing a non-parametric hypothesis test on the difference between sample means for the dry period and the wet period. The test is repeated on the pair of samples created by every possible break point year between dry and wet periods. The year that provides the strongest evidence of a difference in sample means is chosen as the break point between dry and wet. Figure 3 displays the p-value or significance of the hypothesis test at each year. A p-value of 5% is often chosen as adequate evidence of an alternative hypothesis, meaning that there is a 5% chance of accepting the alternative hypothesis (sample means are not the same) when it is not true. For this data set, p-values are a lower than 5% by several orders of magnitude. This computation suggests that the year 1941 it the break point with the greatest evidence of the record containing two different flow regimes, and that year was chosen as dividing year between dry and wet periods.

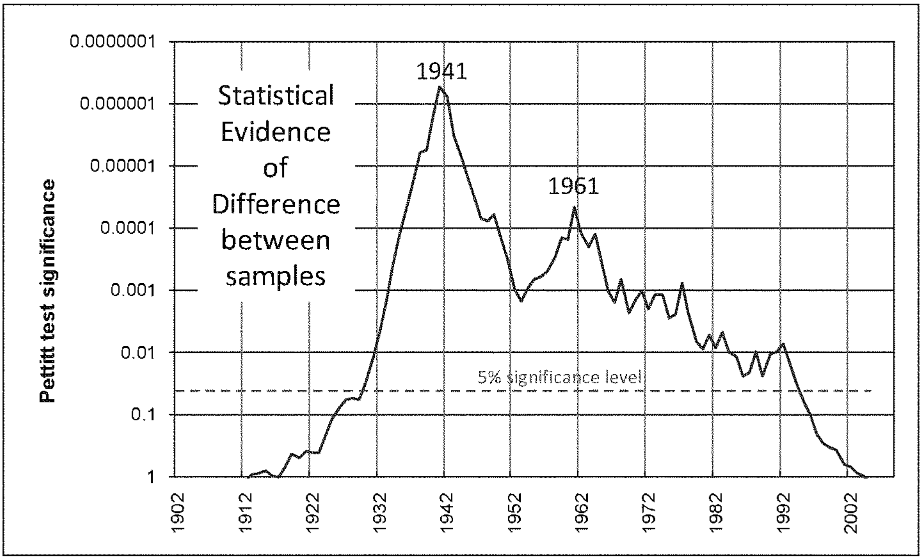


Figure 3. Results of Pettitt test to choose dry/wet break point.

Figure 4 contains a view of the unregulated annual peak flow frequency curve at Fargo based on the full period of record, and the separate frequency curves for the wet and the dry periods. Note that when the record split between wet and dry, the resulting variability within each portion is significantly less than the variability of the full record. The resulting smaller standard deviation of both the wet record and the dry record, compared to the full record, generates frequency curves with smaller slope, and therefore lower upper end. Therefore, counter-intuitively, the estimate of a less frequent event such as the 500-year flow is lower for the wet period frequency curve than the full record. However, this result is supported by the logic in dividing the record between wet and dry, and the understanding that for times within the wet period, the full variability of the record will not be experienced, but rather the limited variability of the wet assumption.

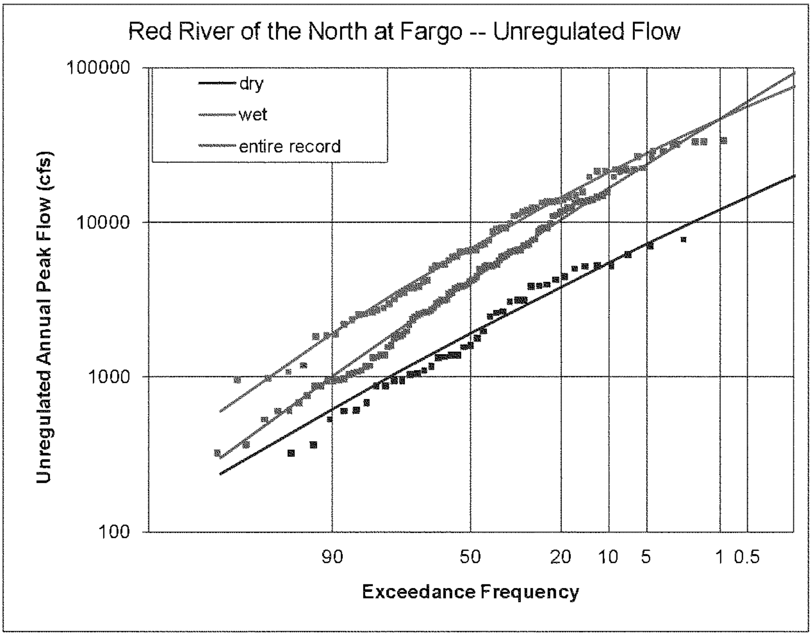


Figure 4. Separate wet and dry period frequency curves, compared to full record.

Develop Unregulated Volume-Duration Frequency Curves

Unregulated volume-duration frequency curves were needed to develop the synthetic flood. Due to reservoirs upstream of Fargo, the natural (unregulated) flows for the Red River were estimated using observed flow measurements and a hydrologic routing model. The St. Paul district provided estimates of natural flows for the entire period of record, including daily average flow time-series at multiple locations on the Red River.

The following description explains how the natural flow time-series were estimated at gaged locations along the Red River. Natural flows were first estimated at the upstream reservoirs and for incremental areas in-between gages. Reservoir inflows were computed using observed outflow and stage. Incremental local flows were estimated by routing observed flows from an upstream gage to a downstream gage and subtracting the routed flow from the measured flow at the downstream gage. For example, the incremental local runoff at the Hickson gage was computed by routing the observed flow at the Wahpeton gage downstream to the Hickson gage. Then, the routed flow was subtracted from the observed flow at the Hickson gage. This computed time-series is the estimated incremental local runoff from the drainage area between the Wahpeton and Hickson gages. Incremental local flows were computed at the Wahpeton, Hickson, and Fargo gages. The St. Paul District used an HEC-5 model and the Straddle Stagger method for routing the time-series to estimate the natural flow time-series. The routing parameters, contained in Table 1, were calibrated to historic flood events.

Once reservoir inflow and incremental local runoff hydrographs were estimated, then the natural flow time-series for the Red River could be computed from upstream to downstream. The natural flow time-series at Wahpeton was computed by routing computed inflows into Orwell and White Rock dams downstream to Wahpeton. Then the routed flow was combined with the incremental local runoff at Wahpeton. The natural flow time-series at Hickson was computed by routing the natural flow time-series from Wahpeton downstream to Hickson and adding the computed incremental local runoff. The natural flow time-series at Fargo was computed by routing the natural flow time-series from Hickson and the observed flow time-series from the Wild Rice at Abercrombie gage to Fargo and adding the incremental local runoff. This analysis resulted in natural flows, daily average flow time-series, from 1942 – 2009. Flows recorded before 1942, prior to White Rock and Orwell dams, were considered natural; therefore, the full period of natural flows at Fargo was 1902 – 2009.

Table 1. Straddle Stagger Parameters used for Hydrologic Routing Model.

Reach	Lag Time (min)	Duration (min)
Wild Rice at Abercrombie Gage to Fargo Gage	2880	7200
Orwell Dam to Wahpeton Gage	1440	4320
White Rock Dam to Wahpeton Gage	1440	4320
Wahpeton Gage to Hickson Gage	2880	7200
Hickson Gage to Fargo Gage	1440	4320

The Hydrologic Engineering Center's Statistical Software Package (HEC-SSP) was used to compute the volume-duration frequency curves at Fargo using the natural flows time-series. The Volume-Duration Frequency Analysis within HEC-SSP extracts the annual maximum flows for each duration specified; in this case the annual maximum 1, 3, 7, 15, and 30-day duration flows were extracted. Once the annual maximums flows were extracted, HEC-SSP fit a Log Person III distribution to each set of annual maximums. In some cases, the skew and standard deviation were manually modified so that frequency curves did not cross one another. For the wet and dry periods, regional skew values were not appropriate and so only station skew coefficients were used.

The peak, 1, 3, 7, 15, and 30-day annual maximum natural flows are contained in Table 2. Peak flows from 1942 – 2009 were estimated from the 1-day flow using a relationship developed by the St. Paul District, the maximum 1-day flow is multiplied by 1.012. Measured peak flows prior to 1942 were considered natural. The 1, 3, 7, 15, and 30-day flows for the two historical events, 1882 and 1897, were estimated using a regression analysis with data in Table 2. For example, the 3-day flows for the 1882 and 1897 events were estimated using a regression analysis of 1 and 3-day flows from 1902 – 2009.

Plots of the volume-duration frequency curves for the wet, dry, and full periods are shown in Figure 5 – Figure 7 (Red River at Fargo). These figures also show the LPIII statistics for each frequency curve. Table 3 - Table 5 contains the 10, 50, 1, 0.5, and 0.2 percents flows for the peak, 1, 3, 7, 15, and 30-day durations (Red River at Fargo). Values in these tables were used to develop the synthetic flood events.

Table 2. Annual Maximum Flows at Fargo - Natural Flows.

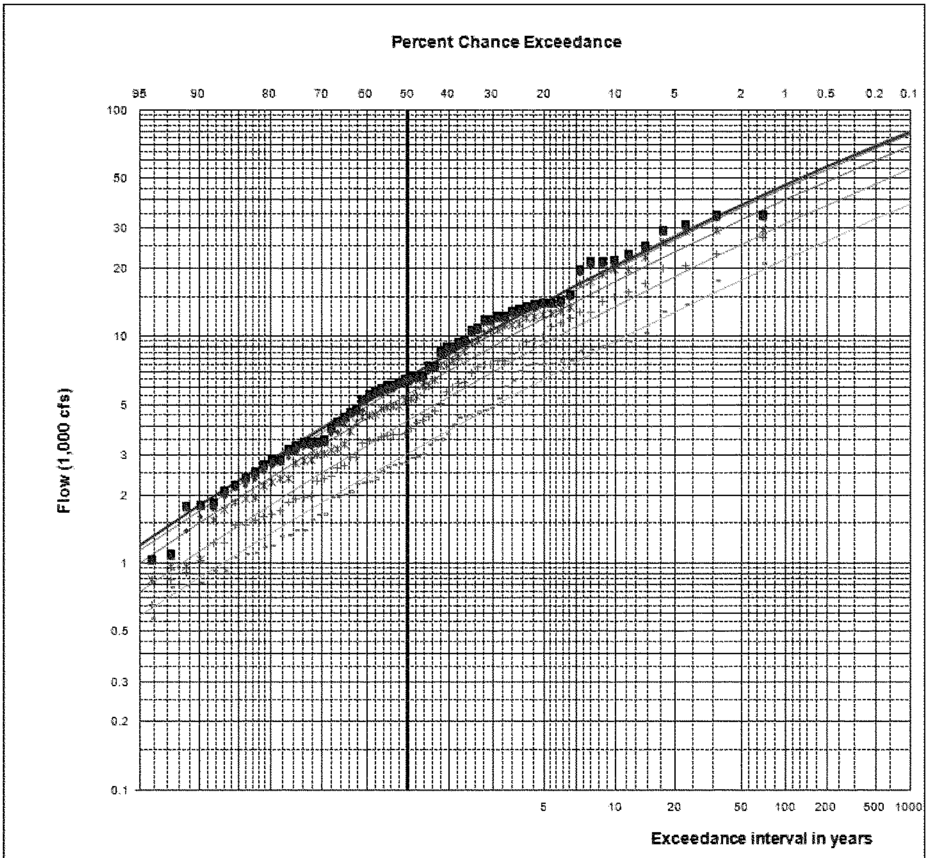
Year	Peak	1-Day	3-Day	7-Day	15-Day	30-Day
1882	20000	19760	19272	17472	13649	9541
1897	25000	24700	24090	21840	17061	11926
1902	1180	1180	1140	1094	966	947
1903	2450	2450	2410	2256	1858	1260
1904	5220	2830	2787	2590	2590	2590
1905	4250	4250	4117	3644	2611	1809
1906	3050	3050	2883	2566	2472	2053
1907	7000	4420	4353	4026	3076	2920
1908	2600	2600	2520	2421	2150	1933
1909	1780	1780	1610	1601	1451	1209
1910	5000	4700	4600	4371	3450	2448
1911	608	608	529	471	415	408
1912	1100	1100	1070	1049	922	753
1913	1560	1460	1430	1283	953	649
1914	3140	3060	2907	2499	1873	1819
1915	3130	3110	3110	2866	2437	2260
1916	7740	7720	7667	7491	6800	6075
1917	5240	5200	5133	4869	3915	3175
1918	874	750	733	692	617	524
1919	680	630	630	596	570	532
1920	6200	6120	5987	5366	3466	2153
1921	1970	1970	1603	1238	937	802
1922	5200	5200	5067	4617	3947	3806
1923	3960	3960	3853	3053	1916	1257
1924	530	530	503	457	381	330
1925	940	885	885	806	751	614
1926	1600	1600	1447	1282	917	652
1927	2650	2650	2463	2023	1325	1194
1928	3840	3840	3787	3359	2088	1227
1929	4440	4440	4387	4017	2692	1629
1930	1340	1340	1320	1244	1027	805
1931	365	365	325	268	229	194
1932	875	868	763	556	360	243
1933	605	605	588	458	347	252
1934	323	323	298	240	163	106
1935	942	930	930	871	656	448
1936	1050	1050	990	904	641	530
1937	1390	1300	1300	1117	724	578
1938	1350	1160	814	575	496	428
1939	3870	3600	3540	3203	2201	1297
1940	1030	970	970	876	697	471
1941	1390	1390	1323	1185	979	709
1942	4639	4584	4479	4174	3394	2897
1943	19709	19475	18828	17114	12719	7561
1944	5691	5624	5506	4941	3672	2708
1945	8556	8455	8229	7381	5666	3720
1946	7423	7335	6917	6031	4169	2787

Table 2. Continued.

Year	Peak	1-Day	3-Day	7-Day	15-Day	30-Day
1947	11840	11700	11510	10336	7318	4733
1948	4795	4738	4688	4421	3670	2634
1949	3412	3372	3231	2759	1932	1177
1950	8973	8867	8538	7828	6249	4634
1951	10700	10573	10407	9556	6919	4433
1952	21643	21386	21207	19770	15604	9541
1953	6529	6452	6020	4904	4247	3489
1954	2084	2059	1951	1840	1693	1390
1955	3171	3133	2905	2348	1592	1110
1956	3968	3921	3694	3177	2288	1622
1957	3489	3448	3319	2855	1927	1194
1958	2379	2351	2186	1724	1231	797
1959	1815	1793	1722	1552	1222	925
1960	4410	4358	4056	3344	2614	2007
1961	883	873	851	763	578	494
1962	11851	11710	11511	10688	8337	7588
1963	6651	6572	6205	5207	3906	2534
1964	2718	2686	2513	2178	1844	1549
1965	13889	13724	13038	11206	7546	4462
1966	14366	14196	13704	12034	9050	6031
1967	6722	6642	6443	5447	3616	2744
1968	1096	1083	1061	968	841	777
1969	34202	33796	32817	28945	20506	12832
1970	2527	2497	2328	1944	1470	1317
1971	2847	2813	2676	2257	1634	1328
1972	9721	9606	9368	8535	6167	4076
1973	2215	2189	2131	1927	1472	1056
1974	4210	4160	3769	2822	1965	1387
1975	14147	13979	13736	12891	9998	7010
1976	3406	3366	3236	3039	2346	1637
1977	636	628	536	499	400	360
1978	23063	22790	22064	19702	15021	9479
1979	21375	21122	20683	18873	14254	8747
1980	6148	6075	5692	4825	3479	2233
1981	1840	1818	1382	848	521	476
1982	7406	7318	7167	6430	4431	2942
1983	1788	1767	1598	1041	1029	922
1984	12266	12121	11827	10642	7749	4825
1985	5874	5804	5521	4460	3585	2263
1986	13522	13362	13132	12151	9554	7847
1987	3284	3245	3062	3827	2939	2064
1988	1041	1029	1005	969	903	820
1989	21338	21085	20358	17414	12793	7525
1990	917	906	842	797	651	572
1991	3441	3400	3334	3012	2413	1951
1992	2864	2830	2744	2347	1534	1092
1993	12929	12776	12437	11124	7762	6401
1994	13175	13019	12887	12691	11410	7476

Table 2. Continued.

Year	Peak	1-Day	3-Day	7-Day	15-Day	30-Day
1995	14145	13977	13808	12509	11964	9007
1996	10920	10791	10441	9403	7538	5343
1997	31080	30711	30480	29519	27462	20935
1998	9452	9340	9102	8114	5941	4407
1999	5525	5459	5261	4512	3720	3320
2000	5248	5186	4573	3152	2678	2287
2001	29432	29083	28483	26012	20049	13857
2002	6084	6012	5755	4838	2910	1955
2003	8995	8888	8616	7458	5051	3505
2004	6273	6199	6053	5267	3480	2354
2005	12309	12163	11974	11358	9494	7786
2006	25019	24722	24102	22143	16991	10293
2007	15292	15111	14728	13417	11080	8591
2008	6642	6563	6396	6056	4703	3008
2009	34357	33950	33157	29542	23024	17615



STATISTICS:

	Mean	Std.Dev.	Skew
Peak	3.802	0.415	-0.3
1-day	3.797	0.415	-0.3
3-day	3.778	0.418	-0.3
7-day	3.723	0.418	-0.3
15-day	3.606	0.424	-0.3
30-day	3.467	0.408	-0.3

RED RIVER

VOLUME-FREQUENCY CURVES
FARGO
UNREGULATED CONDITIONS WET

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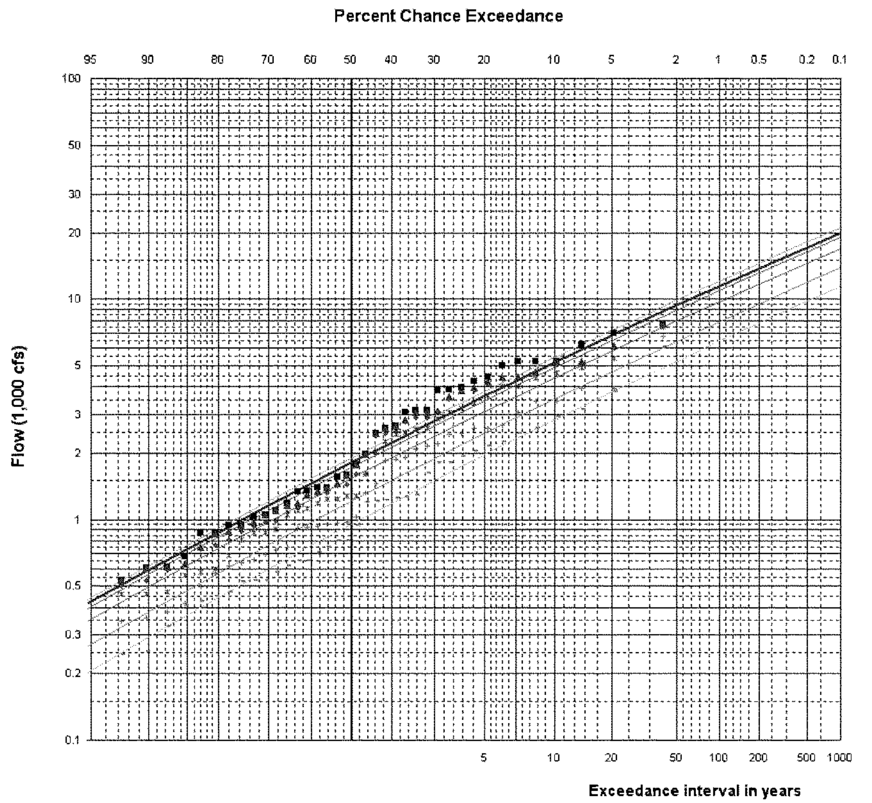
Figure 5. Volume-Duration Frequency Curves for the Wet Period, Red River at Fargo.



STATISTICS:

	Mean	Std.Dev.	Skew
Peak	3.270	0.368	-0.2
1-day	3.249	0.367	-0.2
3-day	3.227	0.367	-0.2
7-day	3.177	0.370	-0.2
15-day	3.073	0.377	-0.2
30-day	2.969	0.384	-0.2

RED RIVER

VOLUME-FREQUENCY CURVES
FARGO
UNREGULATED CONDITIONS DRY

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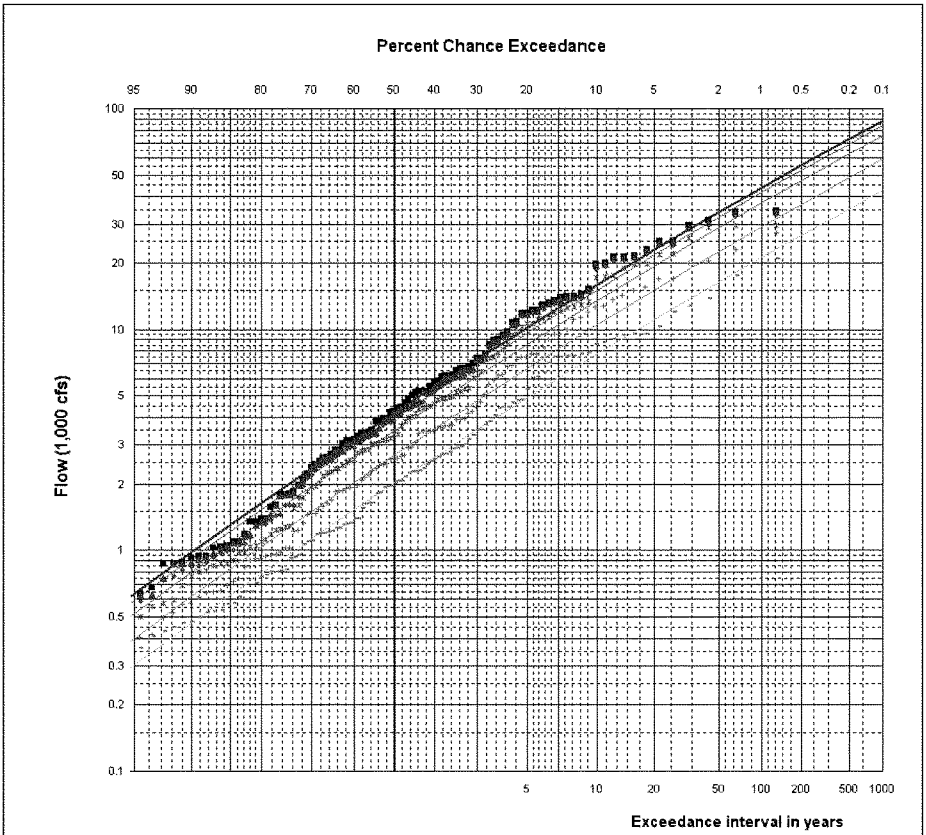
Figure 6. Volume-Duration Frequency Curves for the Dry Period, Red River at Fargo.



STATISTICS:

	Mean	Std.Dev.	Skew
Peak	3.611	0.475	-0.2
1-day	3.608	0.474	-0.2
3-day	3.581	0.476	-0.2
7-day	3.527	0.479	-0.2
15-day	3.416	0.480	-0.2
30-day	3.290	0.475	-0.2

RED RIVER

VOLUME-FREQUENCY CURVES
FARGO
UNREGULATED CONDITIONS FULL PERIOD OF RECORD

U.S ARMY CORPS OF ENGINEERS

Figure 7. Volume-Duration Frequency Curves for the Full Period of Record, Red River at Fargo

Table 3. Volume-Duration Frequency Curves for Wet Period, Red River at Fargo.

Percent Chance Exceedance	Peak (cfs)	1-Day (cfs)	3-Day (cfs)	7-Day (cfs)	15-Day (cfs)	30-Day (cfs)
10	20811	20572	19862	17515	13611	9500
2	38458	38017	36867	32603	25562	17767
1	47168	46628	45284	40097	31531	21933
0.5	56540	55893	54353	48187	37993	26475
0.2	69931	69130	67330	59789	47287	33063

Table 4. Volume-Duration Frequency Curves for Dry Period, Red River at Fargo.

Percent Chance Exceedance	Peak (cfs)	1-Day (cfs)	3-Day (cfs)	7-Day (cfs)	15-Day (cfs)	30-Day (cfs)
10	5433	5158	4908	4396	3528	2837
2	9877	9356	8903	7954	6453	5248
1	12122	11474	10918	9739	7929	6474
0.5	14581	13792	13124	11684	9545	7821
0.2	18176	17177	16346	14513	11903	9793

Table 5. Volume-Duration Frequency Curves for Full Period of Record, Red River at Fargo.

Percent Chance Exceedance	Peak (cfs)	1-Day (cfs)	3-Day (cfs)	7-Day (cfs)	15-Day (cfs)	30-Day (cfs)
10	16155	15989	15138	13504	10491	7729
2	34198	33970	32290	28941	22520	16460
1	44122	43909	41794	37521	29212	21293
0.5	55463	55301	52702	47382	36908	26837
0.2	72769	72748	69429	62530	48735	35334

Develop Synthetic Flood Hydrographs

The synthetic flood hydrographs were developed to reproduce the 10, 2, 1, 0.5, and 0.2 percent flows on the natural flow volume-duration frequency curves contained in Table 3 - Table 5. Upstream hydrographs (inflows into White Rock and Orwell Dams and flow at the Wild Rice at Abercrombie gage) and local runoff hydrographs (local at Wahpeton, Hickson, and Fargo) were adjusted so that when routed and combined downstream they produce a balanced hydrograph at Fargo. The balanced hydrograph contains the 1 – 30-day volumes for a specific frequency. For example, the balanced 1-percent hydrograph at Fargo for the full period of record analysis contains a maximum 1-day flow of 43909 cfs, 3-day flow of 41794 cfs, 7-day flow of 37521 cfs, 15-day flow of 29212 cfs, and 30-day flow of 21293 cfs.

An HEC-HMS model was used to develop the balanced synthetic hydrographs by routing and combining the upstream and local runoff hydrographs. Figure 8 shows the HEC-HMS model schematic for the Red River above Fargo. Routing parameters in the HEC-HMS model were the same as those in the HEC-5 model developed by the St. Paul District.

The 2006 flood event was selected to shape synthetic flood hydrographs for both the wet period and full period of record analyses, and the 1945 event was used to shape the synthetic flood hydrographs for the dry period analysis. The use of these historic events provides information about the timing of the flood hydrograph. For example, an historic event provides information about how timing of the peak flow on the Wild Rice coincides with the peak flow on the Red River. These flood events were chosen because they are among the largest for their respective analysis periods, the 2006 is among the largest floods on record and the 1945 event is a large flood typical of what occurred during the dry period (1902 – 1941).

HEC-HMS was used because it has an option to ratio the ordinates of all inflow hydrographs. The ratio option was used to adjust the upstream hydrographs (inflows into White Rock and Orwell Dams and flow at the Wild Rice at Abercrombie gage) and local runoff hydrographs (local at Wahpeton, Hickson, and Fargo). Because the ratio option applies a uniform adjustment for all ordinates of the hydrographs, some manual adjustment of the upstream and local runoff hydrographs was needed. For example, the 1-day flow from the 2006 event has a lower annual exceedance probability than the 30-day flow. Uniform adjustment using the ratio option in HEC-HMS would not be able to reproduce a balanced hydrograph at Fargo (the 30-day flow would be too low); therefore, hydrograph shapes were modified. More flow was added to the receding limb of the hydrograph for the 2006 event. Figure 9 shows the estimated incremental local runoff hydrograph at Wahpeton and the hydrograph after manual edits. Notice that flows affecting the 7-day average were reduced and those affecting the 15 and 30-day average were increased. Similar edits were made for all inflow and local runoff hydrographs. In addition, separate edits were made to hydrographs used for the wet, dry, and full period analyses. These manual adjustments were made in conjunction with adjustments to the ratio option in HEC-HMS with the goal to create balanced hydrographs at Fargo.

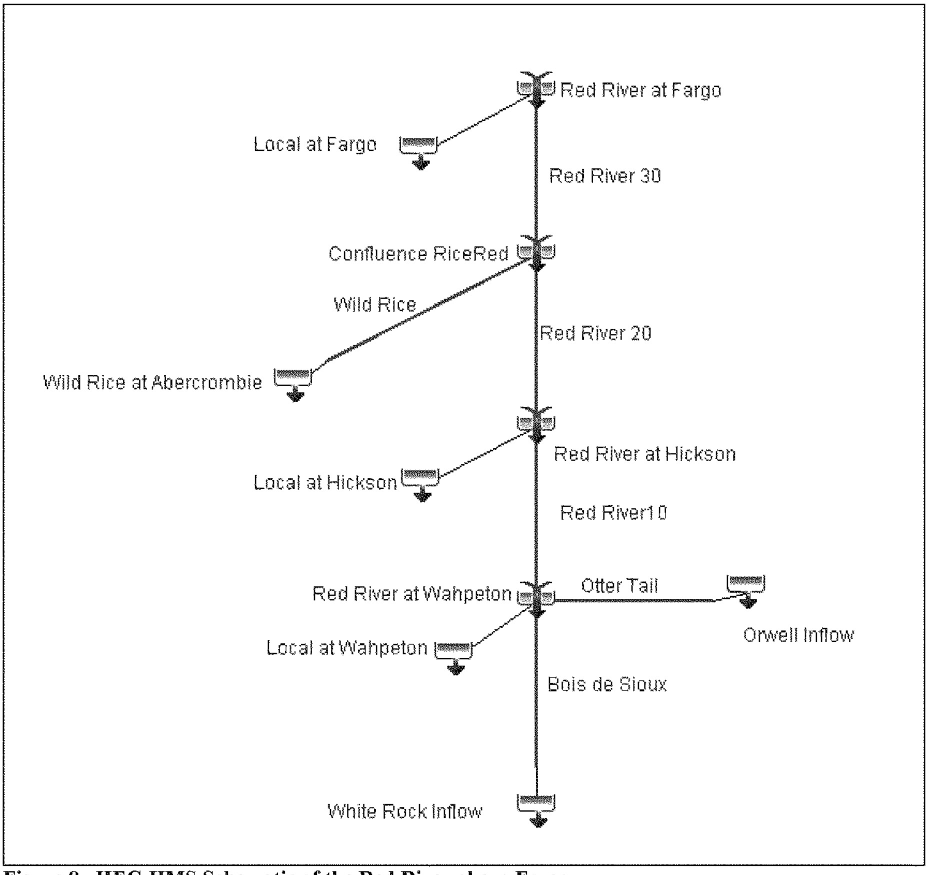


Figure 8. HEC-HMS Schematic of the Red River above Fargo.

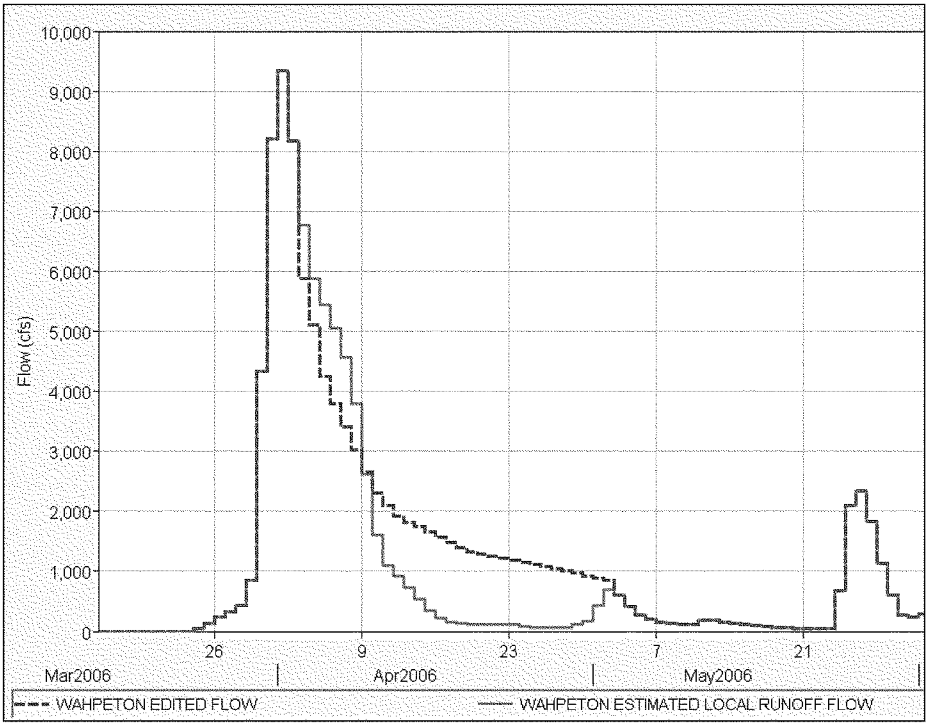


Figure 9. Example of Manual Adjustments of a Local Runoff Hydrograph.

Using HEC-HMS to develop the synthetic hydrographs was an iterative procedure. After a flow ratio was applied to the inflow and local runoff hydrographs, the computed flow time-series at Fargo was exported from HEC-HMS to a spreadsheet and the 1, 3, 7, 15, and 30-day average flows were computed. The maximum flow from each duration was then compared with the appropriate values from the natural conditions volume-duration frequency curves, Table 3 - Table 5. The ratio was then increased or decreased to improve the results. An effort was made to match the 1-day flows for each frequency event, 10, 2, 1, 0.5, and 0.2. For the maximum 3, 7, 15, and 30-day flows an effort was made to ensure that HMS results were within 5-percent of the natural conditions volume-duration frequency curves.

Figure 10 and Figure 11 show the inflow and local runoff hydrograph that reproduce the 1-percent 1, 3, 7, 15, and 30-day flows at Fargo (full period of record analysis). Figure 11 illustrates how the inflow and local runoff hydrographs are referenced in the HEC-HMS model. As shown, six hydrographs are routed and combined to create the final hydrograph at Fargo. A separate set of hydrographs were developed for each frequency event, 10, 2, 1, 0.5, and 0.2-percent events. Figure 12 shows how the local runoff hydrograph at Wahpeton varies for the different frequency events. In addition, synthetic hydrographs were developed for the wet, dry, and full period analyses. This results in 15 different simulations with 6 hydrographs for each. Table 6 – Table 8 contain the maximum 1, 3, 7, 15, and 30-day flows at Fargo from the synthetic hydrographs generated by the HEC-HMS model. Values in these tables compare favorably to the natural volume-duration frequency curves in Table 3 - Table 5.

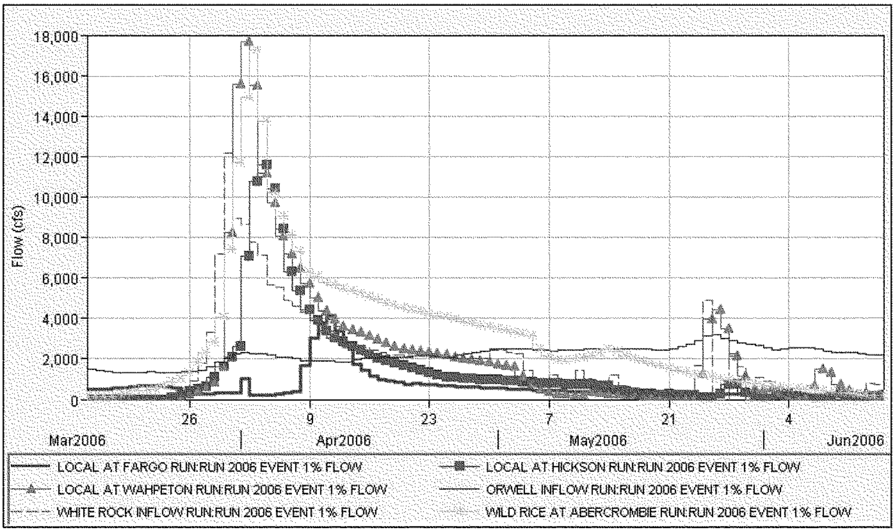


Figure 10. Upstream and Local Runoff Hydrographs that Produce the 1-Percent 1, 3, 7, 15, and 30-Day Flows at Fargo.

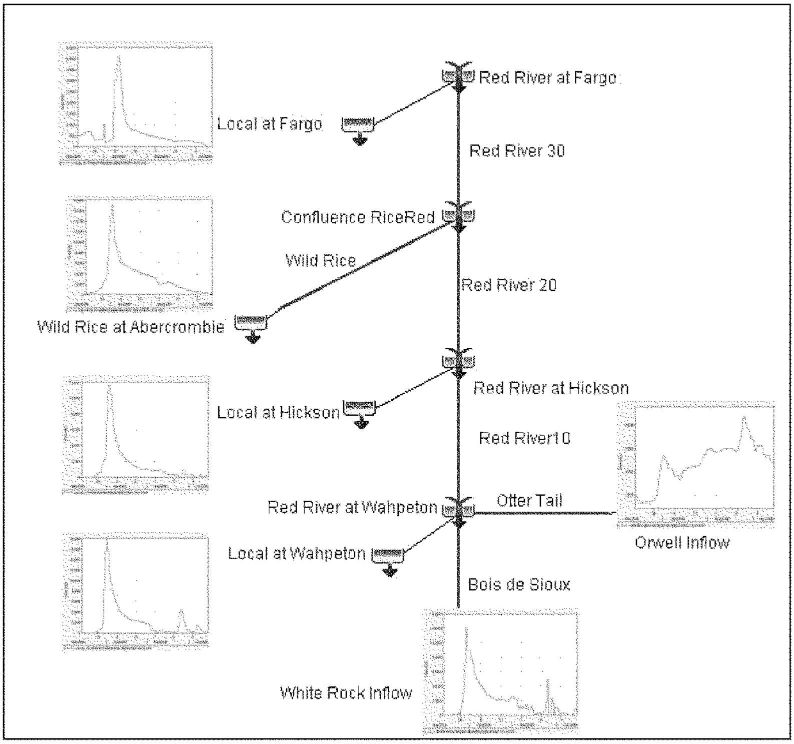


Figure 11. HEC-HMS Schematic of Upstream and Local Runoff Hydrographs that Produce the 1-Percent 1, 3, 7, 15, and 30-Day Flows at Fargo.

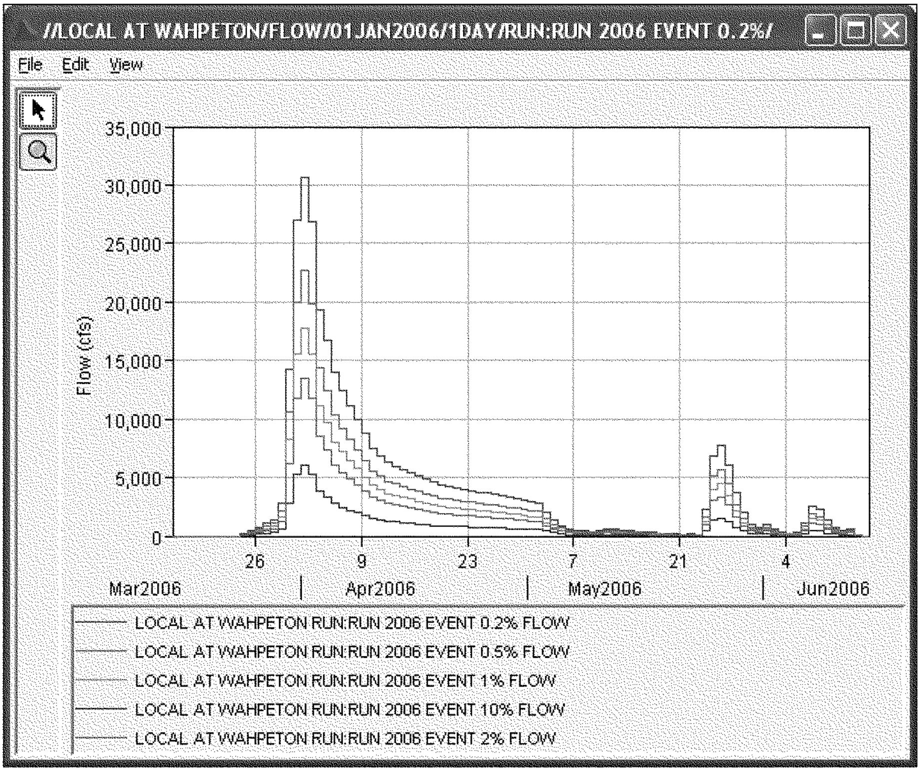


Figure 12. Local Runoff Hydrographs at Wahpeton for the 10, 2, 1, 0.5, and 0.2-Percent Events (Full Period Analysis).

Table 6. Synthetic Events Volume-Duration Results from HMS-Model - Wet Period (compare to Table 3).

Percent Chance Exceedance	1-Day (cfs)	3-Day (cfs)	7-Day (cfs)	15-Day (cfs)	30-Day (cfs)
10	20572	20129	18096	14319	9660
2	38035	37216	33458	26473	17859
1	46609	45604	40999	32440	21885
0.5	55905	54700	49177	38910	26250
0.2	69126	67636	60807	48112	32458

Table 7. Synthetic Events Volume-Duration Results from HMS-Model - Dry Period (compare to Table 4).

Percent Chance Exceedance	1-Day (cfs)	3-Day (cfs)	7-Day (cfs)	15-Day (cfs)	30-Day (cfs)
10	5158	4908	4499	3698	2841
2	9356	8902	8159	6707	5153
1	11474	10918	10007	8226	6320
0.5	13792	13124	12029	9888	7597
0.2	17177	16344	14981	12315	9462

Table 8. Synthetic Events Volume-Duration Results from HMS-Model - Full Period (compare to Table 5).

Percent Chance Exceedance	1-Day (cfs)	3-Day (cfs)	7-Day (cfs)	15-Day (cfs)	30-Day (cfs)
10	15994	15449	13684	10759	7725
2	33983	32825	29074	22860	16413
1	43911	42415	37568	29538	21208
0.5	55300	53416	47313	37200	26709
0.2	72748	70270	62240	48937	35136

Route the Unregulated Synthetic Flood Hydrographs through the HEC-5 Model

The St. Paul District provided an HEC-5 model that was used to route the natural conditions hydrographs through Orwell and White Rock Dams. Output from the HEC-HMS model was referenced by the HEC-5 input file as boundary conditions (inflows) for the reservoirs. 15 simulations were run using the HEC-5 model; 5 frequency events for the wet, dry, and full period analyses. Figure 10 shows the inflow and regulated outflow hydrographs for White Rock Dam from the 0.2-percent event (full period analysis). The HEC-5 model provided output, regulated flows, at the Hickson gage. These regulated flows were used as an upstream boundary condition for an unsteady HEC-RAS model.

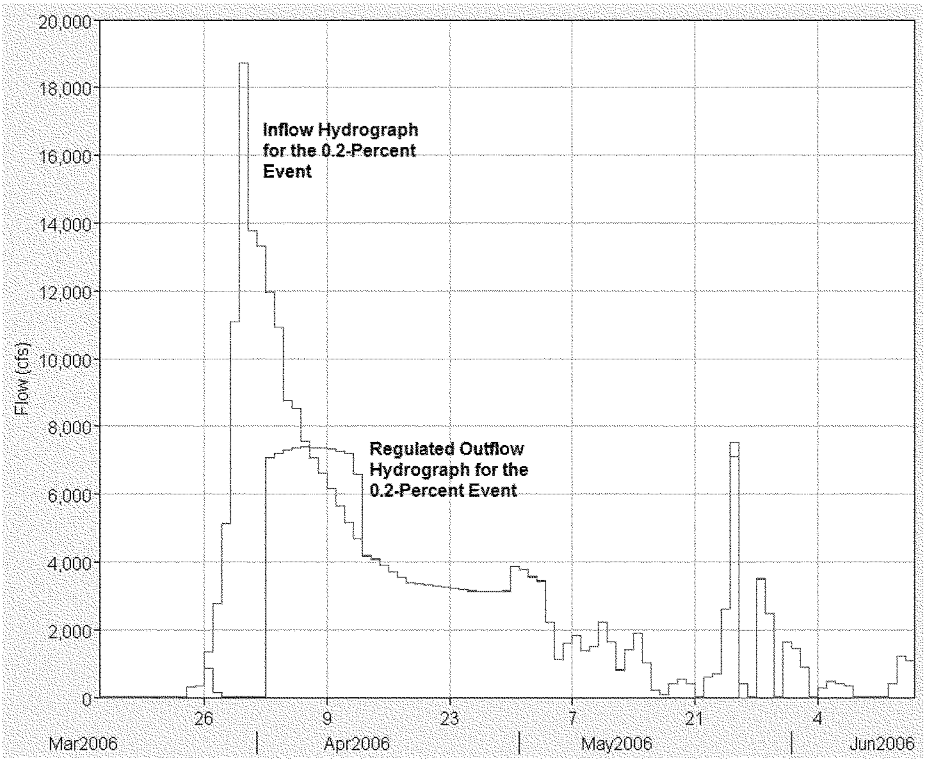


Figure 13. White Rock Inflow and Outflow Hydrographs for the 0.2-Percent Event – Full Period Analysis.

Route Synthetic Hydrographs to Fargo using HEC-RAS

The St. Paul District provided an HEC-RAS model of the Red River. This model was used to route regulated flow at Hickson, computed by the HEC-5 model, downstream to Fargo as well as the synthetic hydrographs from the Wild Rice at Abercrombie gage, developed by the HEC-HMS model, downstream to Fargo. The local runoff hydrographs for Fargo (includes runoff from areas downstream of the Hickson and Abercrombie gages and upstream of Fargo and were also developed by HEC-HMS model) were treated as uniform lateral inflows by the HEC-RAS model.

The HEC-RAS model, as received from the St. Paul District, was modified before it was used to run the synthetic flood events. All geometry below the "RoseC to Shey" reach was removed in order to shorten the compute time. The removal of the downstream geometry had little effect on results at the Fargo cross section.

A total of 15 simulations were run using the HEC-RAS model. These include simulations of the 10, 2, 1, 0.5, and 0.2-percent events for the wet, dry, and full period analyses. Output from the HEC-RAS model was the summation of flows from cross section 2383053 and storage area connections 139, 149, and 156. Table 9 contains the peak flows at Fargo from the synthetic flood events.

Table 9. Peak Flows at Fargo from Synthetic Floods – Output from HEC-RAS Model.

Percent Chance Exceedance	Wet Period (cfs)	Dry Period (cfs)	Full Period (cfs)
10	16676	4654	13089
2	29314	7803	26028
1	34662	9259	32927
0.5	46117	10874	43422
0.2	61693	13318	66199

Add Results from Synthetic Flood Events to the Regulated Flow Frequency Curve

The regulated peak flow frequency curve for the Red River at Fargo was developed using both observed stream flow data and synthetic floods (output from the HEC-RAS model). Table 10 contains regulated annual maximum peak flows for the Red River at Fargo. Gaged peak flows measured after 1942 were treated as regulated. Peak flows prior to 1942 (before upstream dams were constructed) were converted to regulated flow using a regression analysis of measured and estimated unregulated flows from 1942 - 2009.

The regulated peak flow frequency curves were developed graphically by fitting a curve to the observed/estimated annual maximum peaks plotted against empirical frequency estimates, and the synthetic floods plotted against their specified frequencies. Separate frequency curves were developed for the wet, dry, and full periods of record. Table 11 contains both the wet and dry period regulated peak flow frequency curves. Figure 14 and Figure 15 show plots of the regulated curves for the wet and dry periods, respectively. Notice the synthetic floods are used to define the upper end of the regulated flow frequency curves. Table 13 contains the unregulated and regulated peak flow frequency curve for the full period of record analysis and Figure 20 shows both the full period of record analysis unregulated and regulated peak flow frequency curves as well as results from the synthetic floods.

Combine Dry and Wet frequency curves based on assumed future likelihoods

Good statistical evidence of a difference between dry and wet portions of the gaged flood record led to development of a separate peak flow frequency curve for each period. To determine which frequency curve is applicable in any future year, it would be preferable to predict the transition of the apparent cycle from the wet period back to the dry. However, the period of the cycle in unknown and irregular, and there is no way to determine when the current wet regime might shift back to dry. Given this uncertainty in which flow regime will be experienced in the future, the appropriate flood frequency description for any future year is a combination of the dry and wet frequency curves that respects the likelihood of each condition.

Combination of the wet and dry regulated flow frequency curves for a given future year used the total probability theorem, stated as

$$P(Q>q)_t = P(Q>q|wet) * P(wet)_t + P(Q>q|dry) * P(dry)_t$$

with $P(Q>q)_t$ = exceedance probability for a flow q in year t,
$P(Q>q|wet)$ = exceedance probability for flow q given the wet condition
$P(wet)_t$ = probability of the wet condition in year t
$P(Q>q|dry)$ = exceedance probability for flow q given the wet condition
$P(dry)_t$ = probability of the wet condition in year t

This method requires estimating the likelihood of experiencing the wet or the dry condition in any year. For Year 0 of the economic analysis, as we seem to be currently within the wet period, probability of the wet period is set at 100%, and probability of the dry period at 0%. Year 50 is far enough into the future that we cannot make a strong assumption about which hydrologic regime the basin will experience, and so we defer to long-term or steady-state probabilities of the wet versus dry period. Long-term is estimated simply by percentage of the gaged record in each data set, providing 65% chance any future year is in a wet period, and 35% chance it is in a dry period. The assumed probabilities for Year 25 were placed at 80% chance wet and 20% chance dry to be a reasonable estimate between Years 0 and 50.

Using these probabilities, multiple regulated peak flow frequency curves for the Red River at Fargo were developed. That used for Year 0 is simply the wet period curve.

Table 11 also contains the possible future scenario regulated frequency curves that are combinations of both wet and dry curves. These future scenario frequency curves are shown in Figure 16 and Figure 17. For comparison purposes, the unregulated peak flow frequency curve for both wet and dry conditions and possible future scenarios are contained in Table 12 and shown in Figure 18 and Figure 19.

Table 10. Unregulated and Regulated Peak Flows for the Red River at Fargo.

Year	Unregulated Flow (cfs)	Regulated Flow (cfs)
1897	25000	20050
1882	20000	16040
1902	1180	999
1903	2450	2075
1904	5220	4421
1905	4250	3600
1906	3050	2583
1907	7000	5929
1908	2600	2202
1909	1780	1508
1910	5000	4235
1911	608	515
1912	1100	932
1913	1560	1321
1914	3140	2660
1915	3130	2651
1916	7740	6556
1917	5240	4438
1918	874	740
1919	680	576
1920	6200	5251
1921	1970	1669
1922	5200	4404
1923	3960	3354
1924	530	449
1925	940	796
1926	1600	1355
1927	2650	2245
1928	3840	3252
1929	4440	3761
1930	1340	1135
1931	365	309
1932	875	741
1933	605	512
1934	323	274
1935	942	798
1936	1050	889
1937	1390	1177
1938	1350	1143
1939	3870	3278
1940	1030	872
1941	1390	1177
1942	4639	3380
1943	19709	16000
1944	5691	4150
1945	8556	7700
1946	7423	5970

Table 10. Continued.

Year	Unregulated Flow (cfs)	Regulated Flow (cfs)
1947	11840	9300
1948	4795	3390
1949	3412	2660
1950	8973	7800
1951	10700	8010
1952	21643	16300
1953	6529	6720
1954	2084	1920
1955	3171	2760
1956	3968	3870
1957	3489	2540
1958	2379	2280
1959	1815	1250
1960	4410	3900
1961	883	1020
1962	11851	9580
1963	6651	4930
1964	2718	2400
1965	13889	11400
1966	14366	10700
1967	6722	5900
1968	1096	788
1969	34202	25300
1970	2527	2480
1971	2847	1910
1972	9721	7250
1973	2215	1950
1974	4210	4150
1975	14147	13200
1976	3406	3200
1977	636	878
1978	23063	17500
1979	21375	17300
1980	6148	5470
1981	1840	1710
1982	7406	5920
1983	1788	1750
1984	12266	9550
1985	5874	4690
1986	13522	8640
1987	3284	3300
1988	1041	981
1989	21338	18900
1990	917	1220
1991	3441	2630
1992	2864	2590
1993	12929	10100

Table 10. Continued.

Year	Unregulated Flow (cfs)	Regulated Flow (cfs)
1994	13175	11200
1995	14145	11000
1996	10920	9940
1997	31080	28000
1998	9452	8610
1999	5525	4900
2000	5248	5630
2001	29432	20300
2002	6084	4250
2003	8995	6710
2004	6273	5430
2005	12309	9810
2006	25019	19900
2007	15292	13500
2008	6642	4840
2009	34357	29449

Table 11. Regulated Peak Flow Frequency Curves for Wet and Dry Periods and the Combined Frequency Curves.

	Regulated Instantaneous Peak Flow Frequency Curves at Fargo			
Exceedance Frequency	Wet Flow (cfs)	Dry Flow (cfs)	Combine(0.8wet, 0.2dry) Flow (cfs)	Combine(0.65wet, 0.35dry) Flow (cfs)
0.9999	60	50	62	59
0.999	175	95	126	116
0.99	440	200	301	265
0.9	1450	525	989	817
0.75	2800	902	1991	1601
0.5	5600	1610	4352	3506
0.25	10600	2825	8968	7630
0.1	17000	4600	15394	13965
0.05	22000	6100	20345	18855
0.02	29300	8000	27441	25764
0.01	34700	9500	32921	31304
0.005	46200	11000	42242	38787
0.002	61700	13500	57641	54034

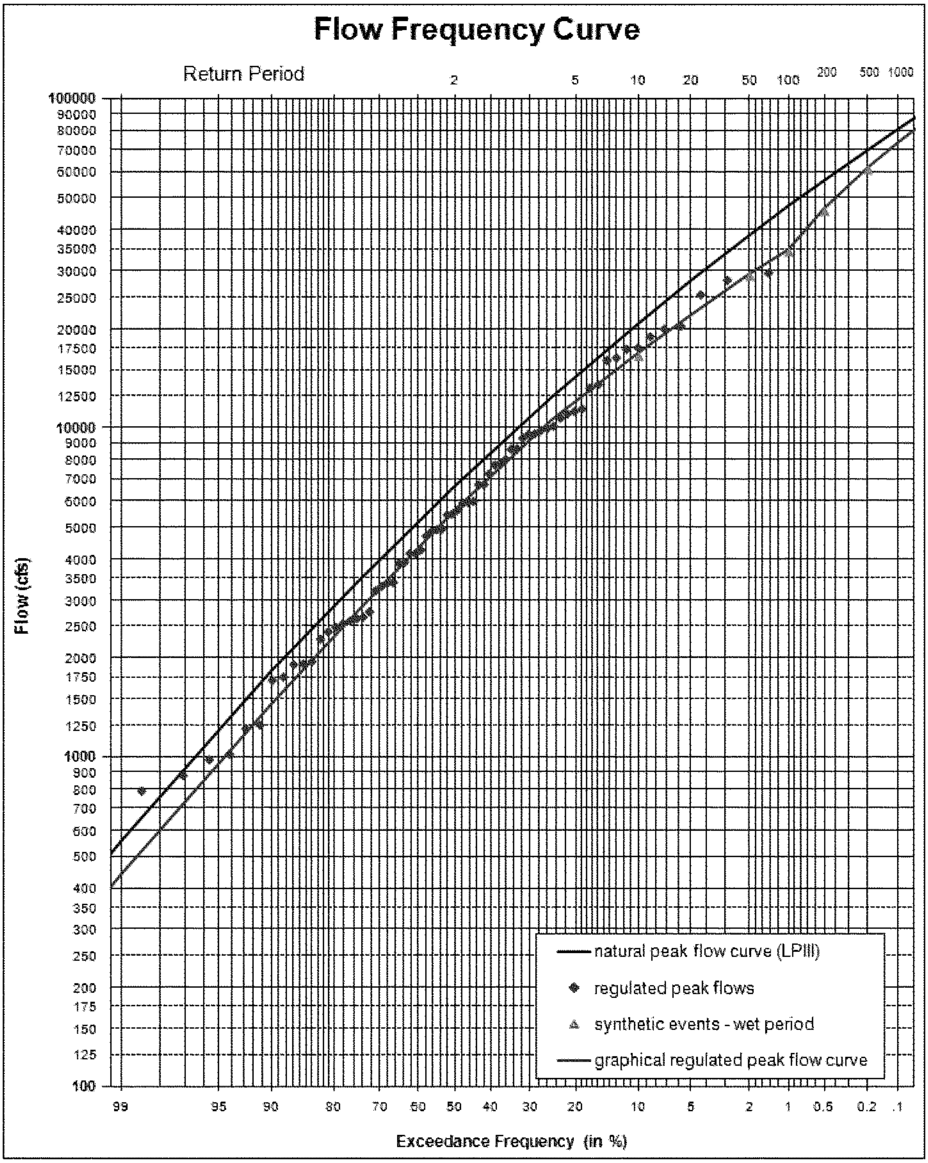


Figure 14. Unregulated and Regulated Peak Flow Frequency Curves with Synthetic Events – Wet Period.

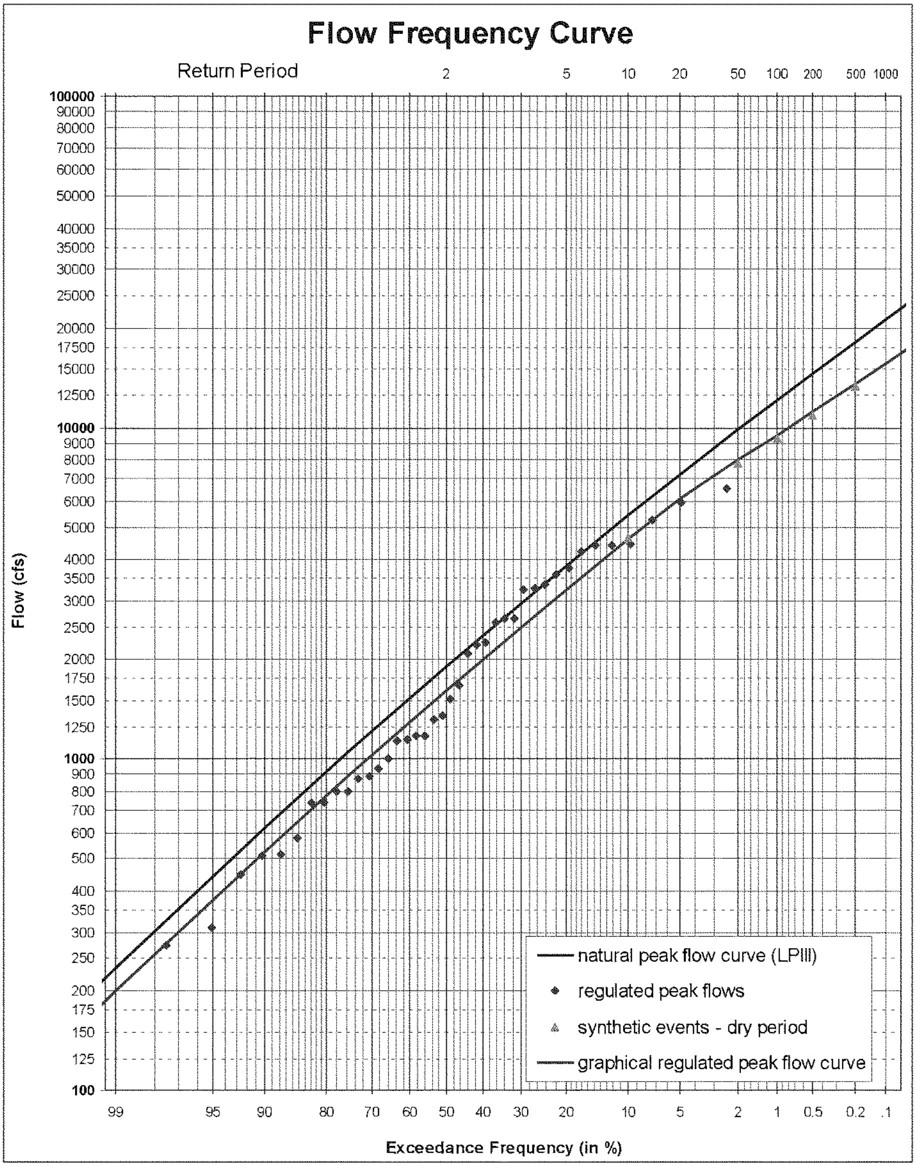


Figure 15. Unregulated and Regulated Peak Flow Frequency Curves with Synthetic Events – Dry Period.

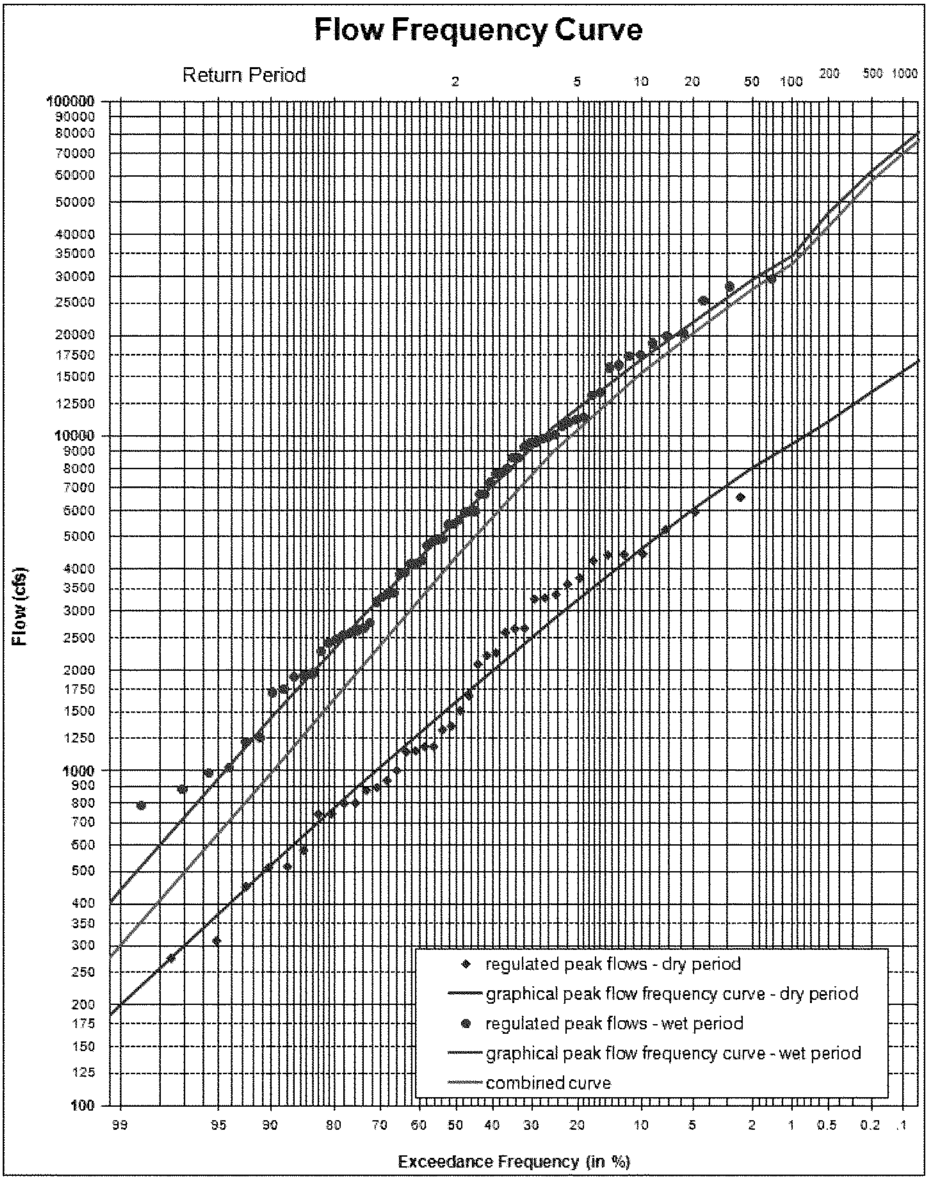


Figure 16. Regulated Peak Flow Frequency Curves for Wet and Dry Periods with Combined Curve (0.8 wet and 0.2 dry weighting).

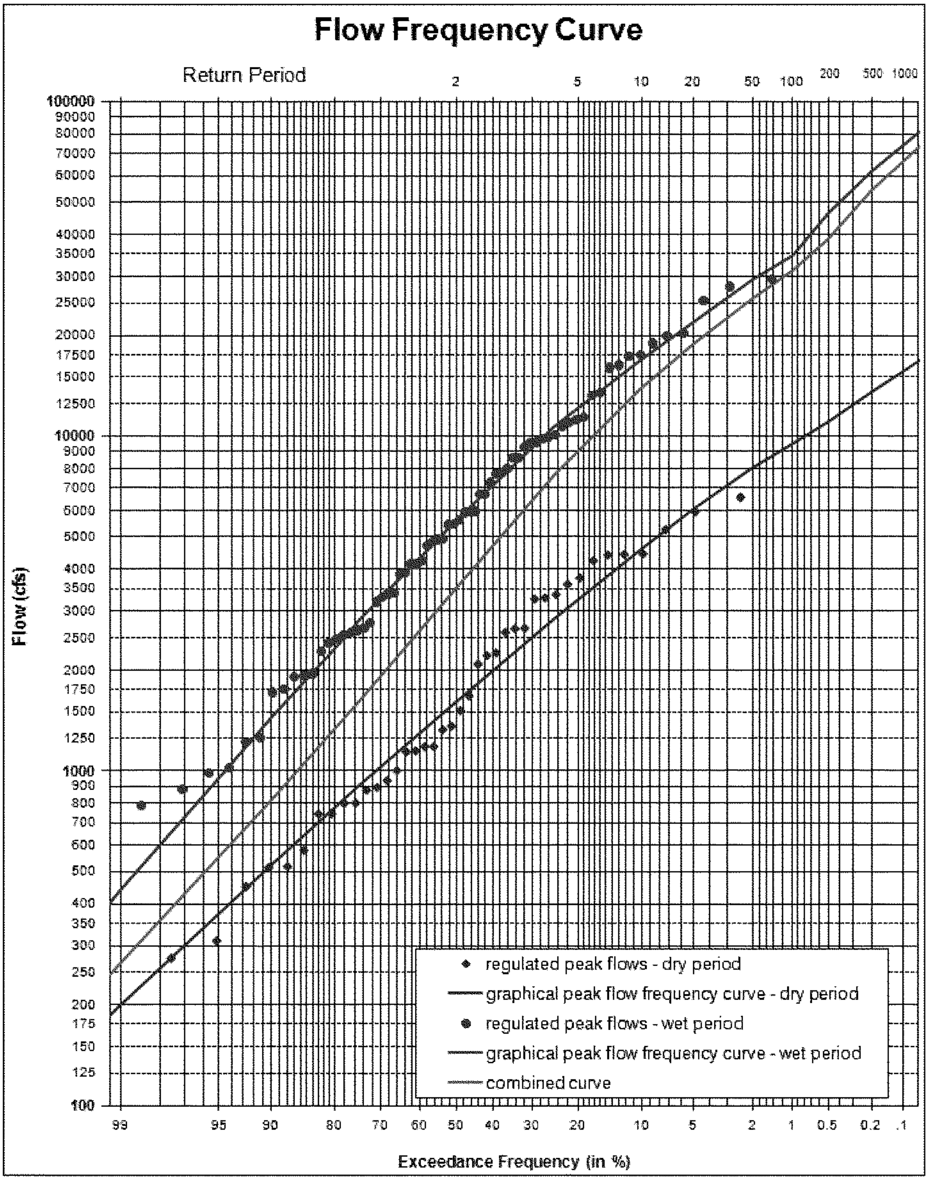


Figure 17. Regulated Peak Flow Frequency Curves for Wet and Dry Periods with Combined Curve (0.65 wet and 0.35 dry weighting).

Table 12. Unregulated Peak Flow Frequency Curves for Wet and Dry Periods and the Combined Frequency Curves.

	Unregulated Instantaneous Peak Flow Frequency Curves at Fargo			
	Wet	Dry	Combine(0.8wet, 0.2dry)	Combine(0.65wet, 0.35dry)
Exceedance Frequency	Flow (cfs)	Flow (cfs)	Flow (cfs)	Flow (cfs)
0.9999	95	59	78	72
0.999	216	112	159	142
0.99	554	235	373	321
0.9	1814	620	1210	983
0.75	3428	1065	2438	1935
0.5	6655	1904	5216	4212
0.25	12362	3336	10534	9017
0.1	20808	5431	18627	16720
0.05	27960	7215	25568	23444
0.02	38445	9865	35744	33326
0.01	47153	12106	44250	41640
0.005	56524	14559	53407	50596
0.002	69914	18145	66504	63420
		Years of Record	62	58
		Mean	3.6879	3.5874
		STDev	0.4680	0.5146
LPIII statistics		Skew	-0.3791	-0.4349

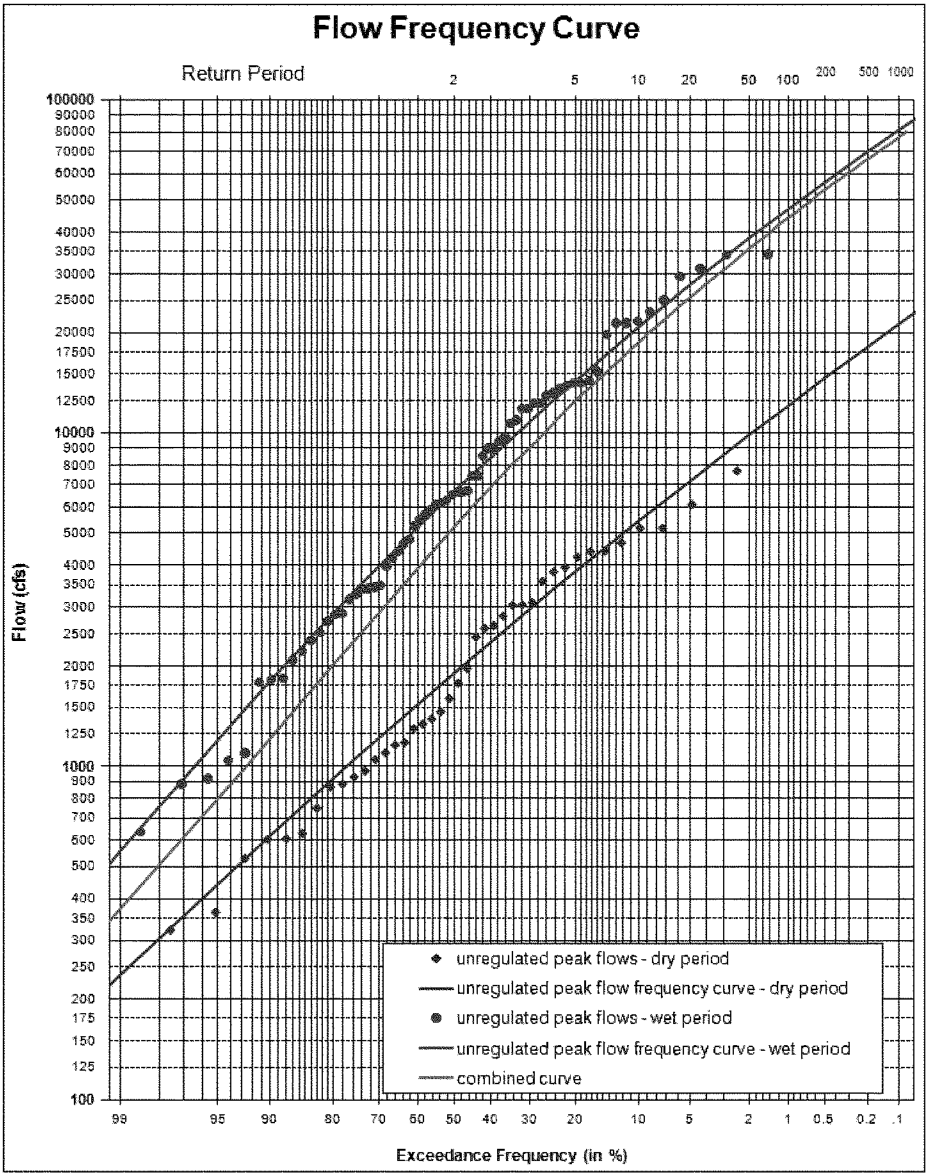


Figure 18. Unregulated Peak Flow Frequency Curves for Wet and Dry Periods with Combined Curve (0.8 wet and 0.2 dry weighting).

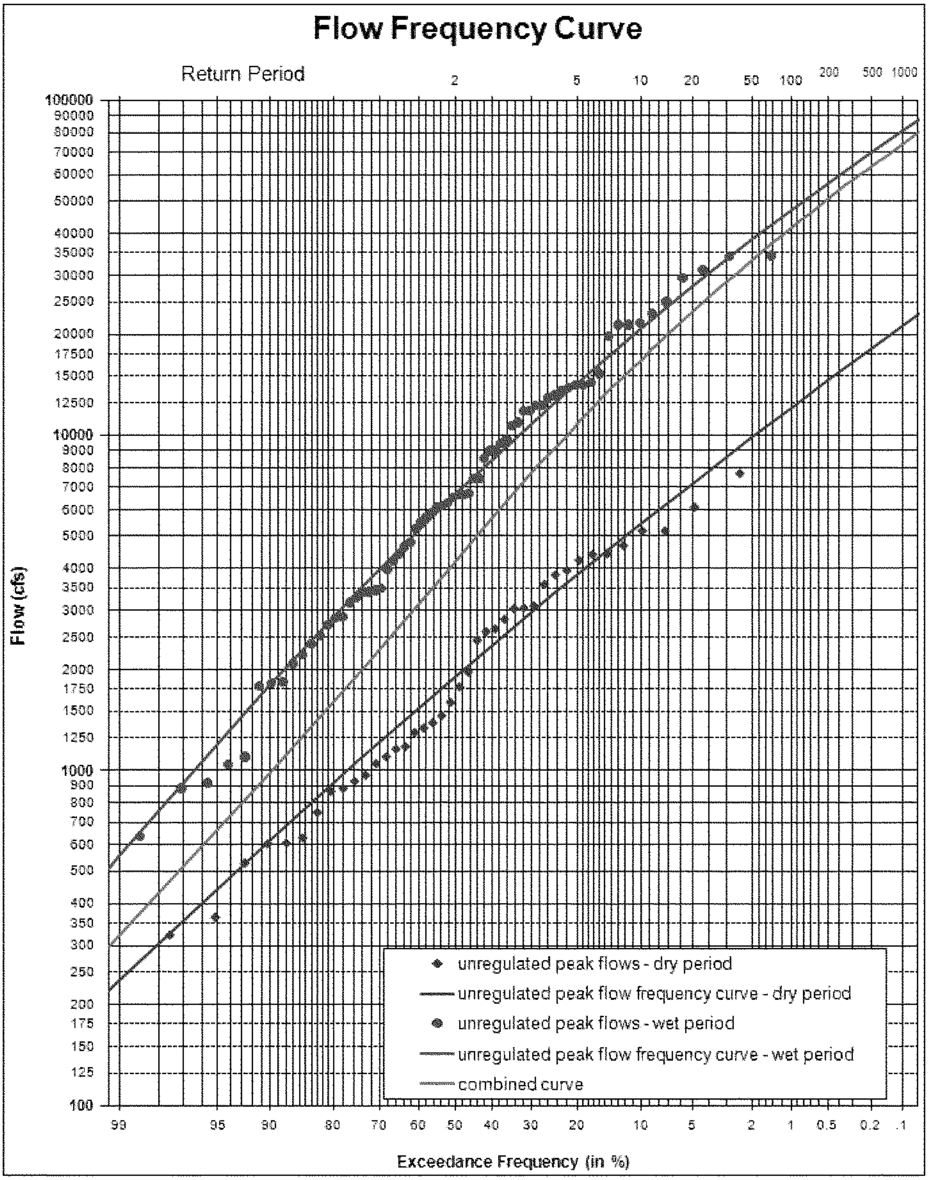


Figure 19. Unregulated Peak Flow Frequency Curves for Wet and Dry Periods with Combined Curve (0.65 wet and 0.35 dry weighting).

Table 13. Unregulated and Regulated Peak Flow Frequency Curves for the Full Period of Record.

Instantaneous Peak Flow Frequency Curves at Fargo - Full Period			
Exceedance Frequency		Unregulated Freq Curve Flow (cfs)	Regulated Freq Curve Flow (cfs)
0.9999		43	37
0.999		101	87
0.99		273	235
0.9		986	846
0.75		1998	1715
0.5		4240	3639
0.25		8699	7467
0.1		16152	13865
0.05		23102	19831
0.02		34183	26000
0.01		44104	33000
0.005		55442	43500
0.002		72746	66000
	Years of Record	128	
	Mean	3.6113	
	STDev	0.4746	
LPIII statistics	Skew	-0.2027	

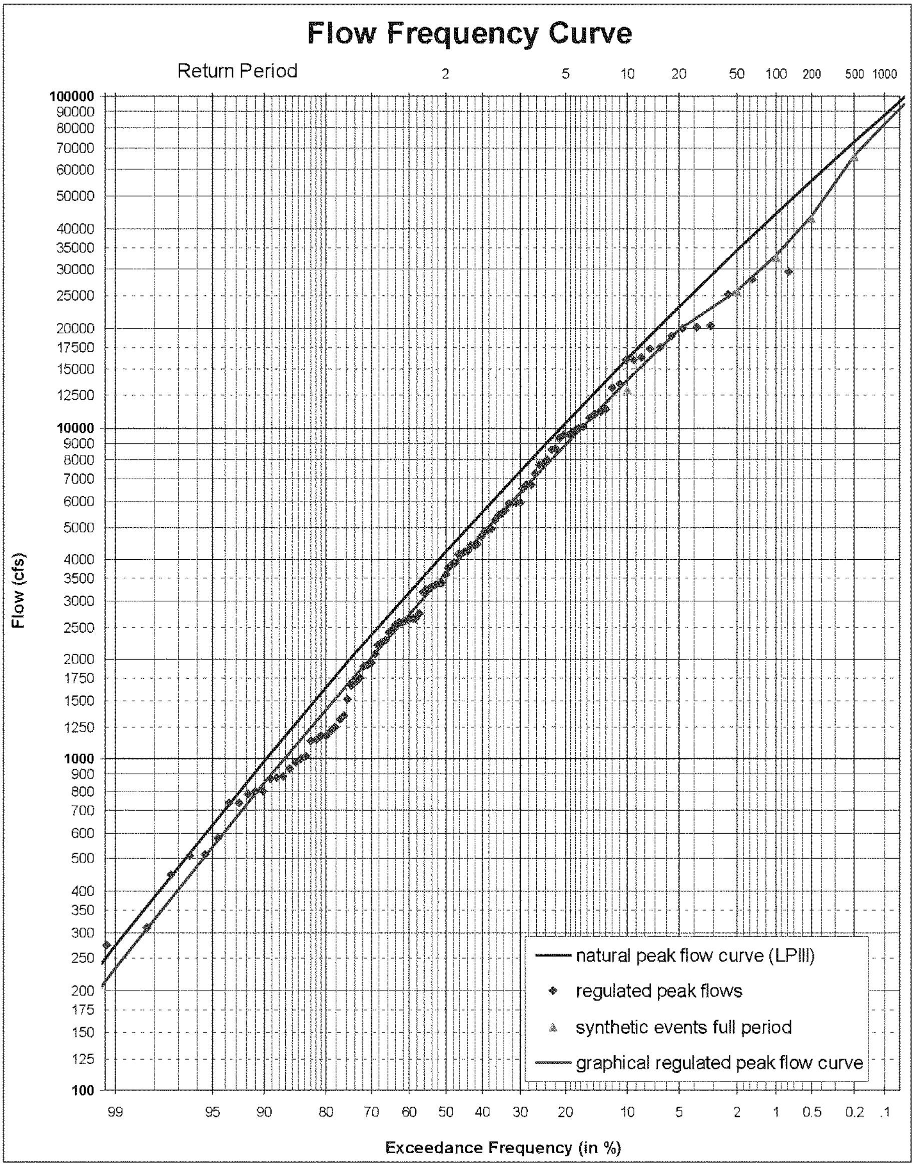


Figure 20. Unregulated and Regulated Peak Flow Frequency Curves with Synthetic Events – Full Period.

Conclusion

The purpose of this study was to develop a regulated peak flow frequency curve for the Red River at Fargo. Due to non-stationarity and an apparent cycle in the observed stream flow record, the stream flow record was divided into a wet period and a dry period, and regulated peak flow frequency curves were developed for both data sets. Then the wet and dry period frequency curves were combined for possible future conditions to estimate the likelihood of the flow regime being wet or dry. For comparison purposes, an additional analysis that incorporated the full period of record was included. The regulated peak flow frequency curves were developed graphically by fitting a curve to the observed/estimated annual maximum peak flows versus empirical frequency estimates and synthetic floods versus their defined frequencies. The synthetic floods were developed using natural conditions volume duration frequency curves, historic hydrograph shapes patterned after floods in 2006 and 1945, an HEC-5 model to regulate flows, and an HEC-RAS model to route the regulated flows from the HEC-5 model to Fargo. Table 11 contains the regulated peak flow frequency curves at Fargo for the wet and dry periods and the possible future conditions. Table 13 contains the regulated peak flow frequency curve at Fargo for the full period of record analysis.

Appendix A-2
Hydrology

Fargo-Moorhead Metropolitan Area Flood Risk Management

Supplemental Draft Feasibility Report and Environmental Impact Statement

April 2011

US Army Corps
of Engineers ®

Prepared by:
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Preface

This Appendix begins by providing an overview of the discussion and ensuing analysis that catalyzed the need to revise the hydrological analysis presented in Appendix A-1 in order to incorporate the effects of climate variability. This is followed by a summary of the Bois de Sioux/ Red River of the North watershed upstream of Fargo, ND. For this phase of the Fargo Moorhead Feasibility Study analysis was not updated for the portion of the watershed upstream of Hickson, ND. A schematic displaying the study area between Lake Traverse and Fargo, ND is displayed in ***Figure 1****.*

This Appendix encompasses revised analysis for the mainstem of the Red River between Hickson, ND and Grand Forks, ND. Schematics displaying the Red River reaches between Fargo, ND and Halstad, MN and Halstad, MN and Grand Forks, ND are displayed in ***Figure 2*** *and* ***Figure 3****, respectively. The revised analysis includes applying statistical analysis to identify a change point in the flow record at Grand Forks in order to confirm analysis carried out at Fargo in Appendix A-1c. After confirming the methodology applied at Fargo, ND the annual peak flow-frequency analysis on the mainstem of the Red River at Hickson, ND, Fargo, ND, Halstad, MN, and Grand Forks, ND were updated for the WET, 25-year Look Ahead Period, and 50-year Look Ahead Period for both the regulated- "With Dam" and unregulated- "Without Dam" conditions. At the end of this report is a discussion describing how to determine confidence limits for these scenarios. This report also includes an updated annual instantaneous peak flow-frequency analysis for the Wild Rice River-ND at Abercrombie, ND.*

In addition to carrying out flow frequency analysis for mainstem locations, this Appendix includes flow-frequency analysis representative of the coincident flows with the peak on the Red River at the mouths of significant tributaries. Coincident flow-frequency analysis was carried out for the WET (1942-2009), 25-year Look Ahead Period, and 50-year Look Ahead Period for the Wild Rice River-ND, Buffalo River, the Wild Rice River-MN, and the Sheyenne River. This Appendix also includes flow-frequency analysis for ungaged locations of interest along the Red River. For ungaged locations between Hickson and Fargo discharge frequencies were based primarily on interpolations between adopted discharge-frequencies at Fargo and Hickson. It also incorporated the coincidental flow-frequencies from the Wild Rice River-ND, Buffalo River and Wild Rice River-MN.

Flow-Frequency analysis is utilized to develop balanced hydrographs which can be used as boundary conditions for hydraulic modeling and to design hydraulic structures. This Appendix describes the methodology used to generate balanced hydrographs. The process requires the development of volume-duration relationships and the 2006 pattern event at points of interests within the study area between Hickson and Grand Forks. Volume duration analysis was carried out either directly by generating volume duration curves based on gaged mean daily flow record or indirectly by utilizing a gaged based volume duration curve located in a hydrologically similar location. The 2006 pattern hydrograph was adopted as a typical event for the Red River Basin and is used to define the timing and shape of balanced hydrographs. There are some limitations to utilizing this methodology to develop balanced hydrographs and this Appendix includes some discussion of these limitations. This Appendix also includes a summary of the initial analysis carried out to determine coincidental flow-frequency curves and balanced hydrographs at the Sheyenne River. The methodology adopted in this Appendix has been updated in Appendices A-3 to A4b.

1. Introduction

The first phase of the discharge-frequency estimates for this study included an analysis based only on the recorded events. Because of the recent record of flooding in the Red River Basin and the apparent dissimilarity between the earlier vs. latter portion of the period-of- record (POR), concerns from technical experts and local stakeholders have been expressed about the effect of climate change or variability on the homogeneity of the POR. To address these concerns the St. Paul District convened a panel of "hydro-climatic" experts to review and provide recommendations. This process follows the Corps guidelines outlined in; "Technical guide for Use of Expert Opinion Elicitation for U.S. Army Corps of Engineers Risk Assessments", (***reference 1***). The results and recommendations from this panel (EOE) are presented as Appendix A-1B.

Following the conclusion of the EOE panel, the St. Paul District contracted with the U.S. Army Corps of Engineers, Hydrologic Engineering Center (HEC) to implement the EOE recommendations for the Fargo frequency curve. This analysis generates three frequency curves: one for the present climate condition labeled as WET, a second labeled as a combination of WET and DRY with 80% weight for WET and 20% weight for Dry, and a third frequency curve combination with a weight of 65% Wet and 35% DRY. The WET curve represents year one in the planning period transitioning to the second combination curve in 25 years and again a transition to the third combination curve at the end of the 50-yr planning period. A description of this methodology is presented in Appendix A-1C.

The hydraulic analysis affirmed the importance of defining the upper end of the discharge-frequency curve, especially since the project design is focused on a 500-yr event. HEC was tasked with supplementing the discharge-frequency analysis, which was based on recorded events, with synthetic events for the upper end of the curve. These events were for the 2-, 1-, 0.5-, and 0.2- exceedance frequency events. This was done not only for the set of WET and DRY curves based on their respective period of record, but also for the entire POR. Therefore, the curves presented in the first part of this appendix were updated and graphically redrawn with these additional plotting positions. HEC did this for Fargo for the POR and combination curves. The St. Paul District did this for Hickson POR curve. The plotting positions for the stations downstream of Fargo were not supplemented in this way.

2. Description of the Watershed

2.1 HEADWATERS

The Bois de Sioux River forms the eastern boundary of both Center Township and Wahpeton, which is also the state boundary between Minnesota and North Dakota. The river follows a winding course northward from White Rock Dam at Lake Traverse until it reaches a confluence with the Ottertail River at Wahpeton, where together they form the Red River of the North.

The Ottertail River rises west of Fergus Falls, Minnesota. The river flows south through a series of lakes until it reaches Ottertail Lake where it turns and flows west to its confluence with the

Bois de Sioux River at Wahpeton. This basin contains more than 1,100 lakes covering more than 15 percent of the total basin area. An additional six percent of the basin is covered by swamps and marshes. The average slope of the Ottertail River from Orwell Dam near Fergus Falls to Wahpeton is three feet per mile.

The watersheds drained by the Bois de Sioux and Ottertail Rivers lie within the former bed of Glacial Lake Agassiz. As a result, most of the Bois de Sioux watershed is a flat lowland glacial plain. The western portion of the watershed is a gently rolling upland glacial plain. The transition zone between the upland and lowland plains is composed of former beach ridges with moderate slopes. The Bois de Sioux River has an average channel slope of approximately 0.3 foot per mile between Lake Traverse and Wahpeton.

Soils in the Bois de Sioux – Ottertail River basin are lacustrine sediments, which are underlain by cretaceous shales with a thin layer of sand in the western half of the basin, and by Precambrian crystalline rocks in the eastern portion. The major land use is agricultural – approximately 91 percent of the basin is used for agricultural purposes. These include grain crops, primarily wheat and corn, and livestock. Less than one percent of the basin is forested.

2.2 WILD RICE RIVER- ND

The Wild Rice River of North Dakota flows easterly from its headwaters in western Sargent County to Lake Tewaukon. At the lake, it turns to follow a northerly course, finally reaching a confluence with the Red River of the North approximately 18 miles south of Fargo. The upper reaches of the Wild Rice River lie within a glacial upland plain. East of Lake Tewaukon, physical features of the watershed include morainic hills, large swamps, low swales and potholes. The average slope of the river is about 1.7 feet per mile; the steepest channel slopes are in the reaches above Lake Tewaukon, where it averages 4.2 feet per mile.

Soils in the Wild Rice basin are lacustrine sediments from Glacial lake Agassiz. Due to the flat topography, natural drainage is very poor. Approximately 78 percent of the watershed is cultivated, and about an additional 14 percent is used for pasture.

2.3 DRAINAGE AREAS- SOUTH OF FARGO

The drainage basin areas for the Wild Rice, Bois de Sioux, Ottertail and Red River of the North are listed in **Table 1**. **Figure 3 of Appendix A-1** shows a schematic with these areas. These drainage areas are divided into primary, secondary and non-contributing drainage areas defined as follows:

A. Primary contributing drainage area is that area which has a direct watercourse to the main stem of the river.
B. Secondary contributing drainage area is the area which begins to contribute during floods greater than the 50-year flood. Secondary contribution area is assumed to be enclosed by a 5-foot contour line on a 7.5 minute USGS topographical map.

C. Non-contributing drainage area is that area which does not contribute to flow. Non-contributing areas are assumed to be enclosed by a 10-foot or more contour line on the 7.5 minute topographical maps.

Table 1. Drainage Areas above Fargo

River	Location	Drainage Area, sq. mi.			
		Primary	Secondary	Non-contributing	Total
Bois de Sioux					
	White Rock Dam	1,160			1,160
	Local areas between White Rock and Wahpeton	807			807
	Above confluence with Ottertail River	1,967			1,967
Ottertail					
	Above Orwell	245		1,585	1,830
	Local area between Orwell & Wahpeton	213		1,585	2,043
	Mouth (Wahpeton)	458			213
Red River of the North					
	USGS Gage @ Wahpeton	2,425		1,585	4,010
	Hickson	2,715		1,585	4,300
Wild Rice- ND					
	Near Mantador	687	120	550	1,357
	CSAH 13 near Wahpeton	895	120	590	1,605
	Abercrombie	1,370	120	590	2,080
Red River					
	Local area between Hickson, Abercrombie, & Fargo	420			420
	Fargo	4,505	120	2,175	6,800

2.4 FLOODING IN THE RED RIVER BASIN

Several different factors cause flooding in the Red River basin. Geomorphologic factors combined with meteorological factors determine the severity of flooding.

The Red River is located in a flat plain, has a shallow, meandering river channel and flows northward. As a result of these landform factors, the timing of spring snowmelt can greatly aggravate flooding in the Red River Basin. Snow in the upstream (southern) portion of the basin melts first, while the downstream (northern) portion of the river remains frozen. This melt pattern increases the likelihood of backwater effects caused by ice jams and frozen river-channel ice. Additionally, the Red River's gentle channel slope of only 0.5 to 1.5 feet per mile (on average) inhibits channel flow and encourages overland flooding.

Spring floods are primarily snowmelt driven. Spring flooding is caused when the basin experiences above-normal fall precipitation followed by the freezing of the saturated ground in either late fall or early winter, before significant snowfall has occurred. These conditions produce a dense layer of frost that limits infiltration of runoff during spring snowmelt. Above normal winter snowfall, precipitation during snowmelt, and high temperatures during snowmelt cause increased flood risk. Summer Floods are caused by intense precipitation, saturated ground and limited vegetative cover. These factors lead to less absorption of water and more runoff (USGS).

3. Nomenclature

Evaluation of the flow characteristics for the Red River of the North at Fargo, ND can be categorized in terms of two conditions. One is with Lake Traverse (White Rock) Dam and Orwell Dam in place. The other condition is without these dams in place. The first section designates these conditions as "regulated" and "natural" conditions, respectively. Phase II of the hydrologic analysis changed the "natural" designation to "unregulated" condition. The without dams condition is interchangeably referred to as the "without dam," "natural" and "unregulated" condition. The with dams condition is interchangeably referred to as the "with dam" or "regulated" condition.

4. Reach Routing Parameters

The Hec-5 model ***(reference 2)*** used the Straddle-Stagger method of routing for "with and without dams" flows. The model routed historic events and the synthetic events down to Fargo. The parameters were based on previous studies done on the Red, most notably the "Volume I, Timing Analysis" (***reference 3***). **Table 2** lists the parameter values for each reach.

Table 2. Hec-5 Reach Routing Parameters

REACH	STRADDLE	STAGGER
Lake Traverse to Wahpeton	3	1
Orwell to Wahpeton	3	1
Wahpeton to Hickson	5	2
Hickson to Fargo	3	1
Abercrombie to Fargo	5	2

5. Flow-Frequency Analysis

5.1 ANNUAL PEAK FLOW-FREQUENCY ANALYSIS- MAIN STEM RED RIVER

Station statistics and flow frequencies were determined for the following USGS gage stations on the main stem of the Red River of the North: Hickson, Fargo, Halstad, and Grand Forks.

5.1.1 Period of Record Based Analysis

The methodology described in Bulletin 17b (***reference 4***) was used to develop the POR curves for the unregulated flow-frequency curves at Fargo, Halstad and Grand Forks. The regulated flow-frequency curve for the POR at Fargo was supplemented with synthetic events. Appendix A-1C describes the methodology.

As described in **Section 4.3** of **Appendix A-1** the USGS gage for the Red River at Hickson, has a relatively short period of record (from 1976 to present). The record at Hickson was back-extended using reconstituted flows from HEC-5 for the regulated condition for the period from 1942 to 1975. The HEC-5 model also generated flows for the unregulated condition from 1942 to present.

To develop the full period of record curve at Hickson as displayed in **Figure 6**, the Hickson event flows were correlated to the long term station at Fargo by assigning plotting positions equivalent to Fargo event plotting positions for the concurrent period and corresponding rank (this methodology is described in greater detail in **Appendix A-1**). To define the upper end of the regulated flow-frequency curve at Hickson, synthetic flood events were determined using the HEC-HMS (***reference 5***) model for the 2-, 1-, 0.5-, and 0.2- percent exceedance frequency events. The methodology used to develop these synthetic events is the same as the method used to develop synthetic events at Fargo as described in Appendix A-1C. Table 3 lists the peak flows at Hickson for the synthetic flood events. The regulated peak flow-frequency curve at Hickson was developed graphically by fitting a curve to the equivalent annual maximum peaks plotted using the Fargo array and the synthetic floods plotted against their specified frequencies.

Table 3. Regulated Peak Flows at Hickson for Synthetic Floods- POR

Red River of the North @ Hickson	
Annual Instantaneous Peaks	
Synthetic Results- Full Period of Record	
Event	Flow (cfs)
500-yr	35,000
200-yr	28,300
100-yr	23,100
50-yr	19,000

Table 4 and **Table 5** lists annual discharge frequency flows and statistics for the unregulated condition based on the period of record (POR) at each gage. The unregulated POR tables represent the annual instantaneous and annual mean daily peak flows, respectively. **Table 6** was developed for the regulated condition. The Flow-Frequency curves for the unregulated and regulated POR at Fargo can be found in **Figure 20** of **Appendix A-1C**.

Figure 4- Figure 6 displays the flow-frequency curves for the POR at Grand Forks, Halstad and Hickson, respectively.

Table 4. Summary Table Statistics- POR Without Dams, Instantaneous Peak Discharge Frequency

Location	Mean Log	Standard Deviation	Adopted Skew	Discharge-Frequency (cfs) % Chance Exceedance				
				10	2	1	0.5	0.2
Hickson[1,2]	3.5272	0.4456	-0.3380	12,000	22,900	28,300	34,200	42,600
Fargo[2]	3.6113	0.4746	-0.2027	16,152	34,183	44,104	55,442	72,746
Halstad[1]	3.9756	0.3994	-0.2674	29,800	54,600	66,900	80,200	99,200
Grand Forks	4.2124	0.3931	-0.2678	50,500	91,700	112,000	134,000	165,000

[1] Two-station comparison
[2] Without-dams condition

Table 5. Summary Table Statistics - POR Without Dams, Mean Daily Peak Discharge Frequency

Location	Mean Log	Standard Deviation	Adopted Skew	Discharge-Frequency (cfs) % Chance Exceedance				
				10	2	1	0.5	0.2
Hickson[1,2]	3.5014	0.4469	-0.338	11,400	21,700	26,900	32,400	40,400
Fargo[2]	3.6004	0.4761	-0.1910	15,848	33,788	43,725	55,124	72,597
Halstad[1]	3.9571	0.4107	-0.2935	29,400	54,300	66,600	79,800	98,700
Grand Forks	4.2035	0.3943	-0.2600	49,719	90,631	110,864	132,695	164,015

[1] Two-station comparison
[2] Without-dams condition

Table 6. Summary Table Statistics – POR *With Dams*, Instantaneous Peak Discharge Frequency

Location	Mean Log	Standard Deviation	Adopted Skew	Discharge-Frequency (cfs) % Chance Exceedance				
				10	2	1	0.5	0.2
Hickson[1,2]		Graphical		8,400	19,014	23,093	28,302	34,974
Fargo[2]		Graphical		13,865	26,000	33,000	43,500	66,000
Halstad[1]	3.9756	0.3994	-0.2674	29,800	54,600	66,900	80,200	99,200
Grand Forks	4.2124	0.3931	-0.2678	50,500	91,700	112,000	134,000	165,000

[1] Two-station comparison
[2] With-dams condition

For the POR curves, a main stem study of skew was performed so that the curves are consistent in their values from upstream to downstream. The station skews were plotted vs. mean. Three different smoothing schemes were looked at including a regression least squares fit and estimates based on 50 percent station skew and 50 percent regression based skew. The Grand Forks station skew was adopted as a regional skew value to weight with the station skews at Fargo and Halstad. The Grand Forks skew was chosen because it is the long-term station on the Red River. Station skew at Hickson was weighted with regional skew values published in the Minnesota USGS publication, "Generalized Skew Coefficients for Flood-Frequency Analysis in Minnesota" **(reference 6)**.

5.1.2 Combined Curves - EOE Based Analysis

Table 7, **Table 8, and Table 9** present summaries for the WET, 25-yr, and 50-year look-ahead conditions at Fargo, Grand Forks, Halstad and Hickson. These curves represent the regulated condition. The WET, 25-yr, and 50-year look-ahead flow-frequency curves were derived based on the EOE recommendations and the guidance given by HEC. For these conditions, only the instantaneous peak flow summaries are provided in the tables.

Table 10, Table 11, and **Table 12** present summaries for the WET, 25-yr, and 50-year look-ahead conditions at Fargo, Grand Forks, and Halstad. These curves are representative of the unregulated condition. The effects of the reservoirs diminish considerably downstream of Fargo, ND due to increasing incremental drainage area. Therefore, Grand Forks and Halstad are not affected by regulatory effects and are thus the same for both the regulated and unregulated condition. Unregulated curves at Hickson were not generated in this phase of the project instead simplifying assumptions were used to generate the required flow-frequency data at that location. This will be further explained in **Section 5.1.4**. The WET, 25-yr, and 50-year look-ahead flow-frequency curves were derived based on the EOE recommendations and the guidance given by HEC. For these conditions, only the instantaneous peak flow summaries are provided in the tables.

Appendix A-1C developed by HEC, which precedes this section of the report describes the methodology used to develop the flow-frequency curves for the WET, 25-Year combined and 50-Year combined curves at Fargo, ND. The plotted flow-frequency curves at Fargo, ND for both the regulated and unregulated condition can be found in the Appendix A-1C in **Figure 14 - Figure 20**. The following sections describe how the corresponding flow frequency curves were developed for gaged locations at Grand Forks, Hickson, and Halstad.

Table 7. Summary Table Statistics – WET With Dams, Instantaneous Peak Discharge Frequency

Location	Mean Log	Standard Deviation	Adopted Skew	Discharge-Frequency (cfs) % Chance Exceedance				
				10	2	1	0.5	0.2
Hickson[1,2,3]		Graphical		10,500	19,000	22,000	28,500	37,000
Fargo[2]		Graphical		17,000	29,300	34,700	46,200	61,700
Halstad[1]	4.099	0.356	-0.2940	34,871	59,306	70,798	82,872	99,713
Grand Forks	4.352	0.320	-0.2870	56,354	91,026	106,838	123,201	145,675

[1] Two-station comparison; [2] With-dams condition; [3] Revised with Hydraulics Guidance

Table 8. Summary Table Statistics – 25-yr Look-Ahead *With Dams*, Instantaneous Peak Discharge Frequency

Location	Mean Log	Standard Deviation	Adopted Skew	Discharge-Frequency (cfs) % Chance Exceedance				
				10	2	1	0.5	0.2
Hickson[1,2]		Graphical		9,555	19,709	23,757	26,164	30,016
Fargo[2]		Graphical		15,394	27,441	32,921	42,242	57,641
Halstad[1]	4.0408	0.3740	-0.3070	32,771	57,006	68,501	80,649	97,734
Grand Forks	4.2990	0.3362	-0.2976	53,213	87,782	103,682	120,244	143,205

[1] Two-station comparison; [2] With-dams condition

Table 9. Summary Table Statistics – 50-yr Look-Ahead *With Dams*, Instantaneous Peak Discharge Frequency

Location	Mean Log	Standard Deviation	Adopted Skew	Discharge-Frequency (cfs) % Chance Exceedance				
				10	2	1	0.5	0.2
Hickson[1,2]		Graphical		8,710	18,543	22,626	24,116	28,246
Fargo[2]		Graphical		13,965	25,764	31,304	38,787	54,034
Halstad[1]	3.9880	0.3970	-0.3407	30,963	54,989	66,482	78,692	95,991
Grand Forks	4.2517	0.3569	-0.3308	50,530	84,960	100,932	117,667	141,059

[1] Two-station comparison; [2] With-dams condition

Table 10. Summary Table Statistics – WET *Without Dams*, Instantaneous Peak Discharge Frequency

Location	Mean Log	Standard Deviation	Adopted Skew	Discharge-Frequency (cfs) % Chance Exceedance				
				10	2	1	0.5	0.2
Fargo	3.802	0.415	-0.307	20,808	38,445	47,153	56,524	69,914
Halstad	4.099	0.356	-0.294	34,871	59,306	70,798	82,872	99,713
Grand Forks	4.352	0.320	-0.287	56,354	91,026	106,838	123,201	145,675

Table 11. Summary Table Statistics – 25-yr Look-Ahead *Without Dams*, Instantaneous Peak Discharge Frequency

Location	Mean Log	Standard Deviation	Adopted Skew	Discharge-Frequency (cfs) % Chance Exceedance				
				10	2	1	0.5	0.2
Fargo	3.6879	0.4680	-0.3791	18,627	35,744	44,250	53,407	66,504
Halstad	4.0408	0.3740	-0.3070	32,771	57,006	68,501	80,649	97,734
Grand Forks	4.2990	0.3362	-0.2976	53,213	87,782	103,682	120,244	143,205

Table 12. Summary Table Statistics – 50-yr Look-Ahead Without Dams, Instantaneous Peak Discharge Frequency

Location	Mean Log	Standard Deviation	Adopted Skew	Discharge-Frequency (cfs) % Chance Exceedance				
				10	2	1	0.5	0.2
Fargo	3.5874	0.5146	-0.4349	16,720	33,326	41,640	50,596	63,420
Halstad	3.988	0.397	-0.3407	30,963	54,989	66,482	78, 692	95,991
Grand Forks	4.2517	0.3569	-0.3308	50, 530	84,960	100,932	117,667	141,059

<u>5.1.3 Flow Frequency Analysis at Grand Forks</u>

As stated in **Appendix A-1,** USGS gaging station 05082500 at Grand Forks, ND is the long-term station on the Red River below the Canadian border. It can be assumed as stated in **Appendix A-1**, that the flows at Grand Forks are not affected by the regulatory effects of the upstream dams. **Table 13** lists annual instantaneous peak flows for the Red River at Grand Forks and **Figure 7** graphically displays this record. Like Fargo, the observed streamflow record at Grand Forks post-1900 suggests an upward trend. However, large events prior to the turn of the century support the theory that cycles between wet and dry periods have been experienced in the Red River of the North basin.

To reflect the cyclic nature of the flow regime at Grand Forks, flow-frequency analysis at Grand Forks was carried out using the same methodology as used in the analysis at Fargo, ND. The annual instantaneous peak discharge-frequency curves for future conditions for the Red River of the North at Grand Forks were based upon the observed streamflows from 1882 through 2009. Historic values for 1826, 1852, and 1861 were not incorporated into the analysis, but were used to further substantiate the cyclic nature of the flow regime in the region.

Table 13. Annual Inst. Peak flows for USGS gaging station 05082500 the Red River at Grand Forks.

Water Year	Stream flow (cfs)	Water Year	Stream flow (cfs)	Water Year	Stream flow (cfs)
1882	75,000	1927	10,600	1972	31,400[1]
1883	38,600	1928	12,200	1973	11,300[1]
1884	20,600	1929	17,100	1974	34,300[1]
1885	13,040	1930	9,610	1975	42,800[1]
1886	10,800	1931	1,630	1976	23,600[1]
1887	7,300	1932	10,400	1977	2,190[1]
1888	19,000	1933	4,380	1978	54,200[1]
1889	3,000	1934	3,210	1979	82,000[1]
1890	3,470	1935	2,920	1980	22,000[1]
1891	6,000	1936	14,500	1981	6,710[1]
1892	23,000	1937	4,180	1982	23,900[1]
1893	53,300	1938	6,660	1983	14,300[1]
1894	16,450	1939	6,720	1984	32,300[1]
1895	2,000	1940	10,000	1985	17,800[1]
1896	21,600	1941	13,400[1]	1986	31,900[1]
1897	85,000	1942	11,000[1]	1987	17,500[1]
1898	4,500	1943	28,200[1]	1988	8,500[1]
1899	9,000	1944	10,400[1]	1989	39,600[1]
1900	4,000	1945	21,300[1]	1990	5,040[1]
1901	14,000	1946	22,000[1]	1991	4,870[1]
1902	15,000	1947	35,000[1]	1992	8,000[1,2]
1903	18,800	1948	34,200[1]	1993	26,200[1]
1904	33,000	1949	15,200[1]	1994	26,800[1]
1905	16,800	1950	54,000[1]	1995	34,800[1]
1906	27,600	1951	23,600[1]	1996	58,400[1]
1907	30,400	1952	23,900[1]	1997	137,000[1]
1908	20,500	1953	14,600[1]	1998	39,700[1]
1909	9,260	1954	9,620[1]	1999	50,000[1]
1910	18,500	1955	15,400[1]	2000	31,500[1]
1911	3,520	1956	21,400[1]	2001	57,800[1]
1912	4,730	1957	14,700[1]	2002	38,000[1]
1913	17,200	1958	7,500[1]	2003	17,000[1]
1914	8,240	1959	6,300[1]	2004	34,300[1]
1915	21,500	1960	17,200[1]	2005	38,300[1]
1916	29,000[2]	1961	3,400[1]	2006	72,800[1]
1917	19,800	1962	26,600[1]	2007	35,300[1]
1918	4,480	1963	10,800[1]	2008	17,700[1]
1919	13,600	1964	13,200[1]	2009	80,000[1]
1920	30,300	1965	52,000[1]		
1921	11,500	1966	55,000[1]	**Superscripts**	
1922	19,000[2]	1967	28,200[1]	[1]effected by regulation	
1923	16,200	1968	9,420[1]	[2]Discharge is estimate	
1924	2,530	1969	53,500[1]		
1925	9,690	1970	23,700[1]		
1926	7,720	1971	15,800[1]		

Notes: 1997 was recorded at 137,000 cfs but 114,000 cfs adopted for Q-frequency analysis & 2009 estimated by COE

As described in the HEC Appendix A-1C, the non-parametric Pettitt test (***reference 7***) was used to determine the best break point in the data record at Grand Forks. **Figure 8** displays the p-value or significance of a possible break point at each year. The results suggest that the year 1942 is the break point with the greatest evidence of the record containing two different flow regimes. This analysis was done as a sensitivity test to confirm that other gages in the basin had a similar statistically determined change point as the flow record at the Fargo, ND gage.

To be consistent with the analysis done at Fargo, 1941 was used as the change point for the analysis at Grand Forks. The wet portion of the curve consisted of the portion of the record from 1942 to 2009 and the dry portion of the record consisted of the portion of the record from 1882 to 1941. Flow-frequency analysis was done for the wet and dry portions of the period of record using a Log Pearson Type III distribution. It is appropriate to use a Log Pearson Type III distribution because flows at Grand Forks are considered unaffected by upstream regulation. Station skew and the median plotting position were used to generate the curves. The wet and dry portions of the record were weighted using the method described in the HEC Appendix A-1C and combined using interpolation in order to produce the 25-year and 50-year look-ahead curves. The flow frequency curve for both wet and dry conditions and the 25-year future condition and the 50-year future condition are plotted in **Figure 9, Figure 10**, and **Figure 11**, respectively.

5.1.4 Flow Frequency Analysis at Hickson

As described in **Section 4.3** of **Appendix A-1** the USGS gage for the Red River at Hickson, has a relatively short period of record (from 1976 to present). The record at Hickson was back-extended using HEC-5 (***reference 2***) output for regulated flows from 1942 to 1975. The back-extended record was combined with the observed streamflow record to develop an equivalent streamflow record for the wet portion of the period of record (1942-2009). These values are in **Table 14**. The regulated flows in this table vary slightly from those presented in **Appendix A-1, Table 22** because a correction was made for the routing parameters between Wahpeton and Hickson. This affected flows that were reconstituted from 1942 to 1975. Flows since 1975 were unadjusted and used as recorded. The flows in the following table are now the adopted flows.

Table 14. Equivalent Annual Instantaneous Peak Flow Record at Hickson

Water Year	Stream-flow (cfs)	Water Year	Stream-flow (cfs)	Water Year	Stream-flow (cfs)
1942	4,318	1965	7,152	1988	826
1943	6,631	1966	5,945	1989	12,000
1944	5,851	1967	3,320	1990	857
1945	5,041	1968	954	1991	2,820
1946	4,049	1969	11,639	1992	1,750
1947	5,990	1970	1,870	1993	6,400
1948	2,950	1971	1,172	1994	6,320
1949	3,003	1972	4,438	1995	8,000
1950	5,477	1973	1,607	1996	6,290
1951	7,556	1974	1,706	1997	13,300
1952	9,248	1975	5,098	1998	4,590
1953	3,854	1976	2,500	1999	3,700
1954	2,381	1977	408	2000	2,750
1955	1,475	1978	9,200	2001	11,500
1956	2575	1979	9,600	2002	3,760
1957	3,017	1980	3,250	2003	4,390
1958	1,150	1981	544	2004	3,140
1959	1,368	1982	4,200	2005	7,090
1960	2,950	1983	824	2006	14,400
1961	720	1984	5,100	2007	9,410
1962	6,834	1985	3690	2008	3,910
1963	5,150	1986	6,720	2009	22,600
1964	2,092	1987	2,460		

The regulated peak flow frequency curve for the wet portion of the period of record for the Red River of the North at Hickson was developed iteratively. For the first iteration the curve was determined graphically using the equivalent streamflow record described above and synthetic floods (based on the output from the HEC-HMS model). This first iteration was used as a starting point and then was revised during a second iteration using guidance received from the hydraulic modeling team.

The flow gages at Hickson and Fargo are located in hydrologically similar areas. Model based synthetic events were only generated for the POR at Hickson. The percent differences between the magnitudes of the synthetic events at Fargo for the POR and the wet portion of the period of record were determined. The percent differences were applied to the synthetic results for POR at Hickson to determine the equivalent synthetic events for the wet portion of the period of record at Hickson. **Table 15** contains the equivalent synthetic events for the wet portion of the record at Hickson.

Table 15. Peak flows at Hickson derived from peak flows at Fargo for the Wet portion of the period of Record.

Red River of the North @ Hickson	
Annual Instantaneous Peaks	
Computed Synthetic Results- Wet Portion of Record*	
Exceedance Frequency	
Event	Flow (cfs)
0.2 %	32,618
0.5 %	30,056
1.0 %	24,317
2.0 %	21,399

The regulated WET peak flow frequency curve for the Red River at Hickson was developed graphically by fitting a curve to the equivalent observed annual maximum peaks plotted against empirical frequency estimates and the equivalent synthetic floods plotted against their specified frequencies.

No "dry" curve exists for the flow record at Hickson so the method used at Fargo cannot be used for the gage at Hickson to get the 25-year and 50-year look-ahead curves. In order to generate the combined curves it was again necessary to use the assumption that Hickson and Fargo are located in hydrologically similar areas. Based on this assumption the percent differences between the wet curve at Fargo and the combined curves at Fargo could be used to translate the wet curve at Hickson into the 25-year combined curve and the 50-year combined curve at Hickson. The graphically fit regulated curves at Fargo were used for this purpose. The flow frequency curve for the WET condition at Hickson is plotted in **Figure 12.** The future scenario frequency curves are shown in **Figure 13** and **Figure 14**.

Based on guidance provided by unsteady HEC-RAS modelers, the upper end of the graphical WET flow-frequency curve at Hickson was revised to reflect insight gained from hydraulic modeling. The final adopted curve is displayed in **Figure 15**.

5.1.5 Flow-Frequency Analysis at Halstad, MN

Annual Instantaneous Peak Flow data is recorded by USGS gage 05064500 at Halstad, MN. As can be seen in **Table 16**, the observed instantaneous annual peak flow record at Halstad only extends back to 1936.

Table 16. Recorded Annual Peak Discharges for Red River @ USGS Gage 05064500 at Halstad, ND

Water Year	Stream-flow (cfs)	Water Year	Stream-flow (cfs)	Water Year	Stream-flow (cfs)
1936	7,670	1963	5,850[6]	1986	17,400[6]
1937	2,660	1964	7,820[6]	1987	9,860[6]
1942	5,060[6]	1965	25,600[6]	1988	5,010[6]
1943	21,800[6]	1966	26,800[6]	1989	26,000[6]
1944	7,200[6]	1967	13,800[6]	1990	2,880[6]
1945	13,300[2,6]	1968	2,350[6]	1991	3,700[6]
1946	10,000[6]	1969	35,700[6]	1992	5,200[2,6]
1947	24,500[6]	1970	11,600[6]	1993	22,500[6]
1948	16,000[6]	1971	5,480[6]	1994	16,600[6]
1949	7,710[6]	1972	16,200[6]	1995	23,300[6]
1950	18,700[6]	1973	6,200[6]	1996	25,200[6]
1951	12,900[6]	1974	17,800[6]	1997	71,500[6]
1952	20,700[6]	1975	39,900[6]	1998	19,200[6]
1953	13,600[6]	1976	9,950[6]	1999	18,100[6]
1954	4,660[6]	1977	2,050[6]	2000	29,100[6]
1955	7,200[6]	1978	28,800[6]	2001	37,900[6]
1956	12,900[6]	1979	42,000[6]	2002	15,000[6]
1957	4,980[6]	1980	12,900[6]	2003	11,900[6]
1958	4,420[6]	1981	3,920[6]	2004	18,200[2,6]
1959	3,780[6]	1982	13,200[6]	2005	21,300[6]
1960	8,600[6]	1983	7,800[6]	2006	43,100[6]
1961	1,900[6]	1984	21,900[6]	2007	24,700[6]
1962	15,900[6]	1985	10,400[6]	2008	15,300[6]
				2009	68,800

[2]Discharge is an Estimate
[6]Discharge is affected by Regulation or Diversion

A "Wet" flow-frequency curve could be developed at Halstad using the observed peak streamflow record from 1942 to 2009. The "Wet" curve at Halstad was plotted using a Log-Pearson Type III as outlined in Bulletin 17b. Median plotting positions and station skew were used for analysis. Due to the abbreviated POR at Halstad no "Dry" curve can be developed from the flow record, so the method used at Fargo cannot be used for get the 25-year and the 50-year combined look-ahead curves.

The USGS gage on the Red River of the North at Halstad is located downstream of the USGS gage at Fargo and upstream of the USGS gage at Grand Forks. To develop the combined curves at Halstad a linear regression was performed using the unregulated flow-frequency curves at

Fargo and the flow-frequency curves at Grand Forks. This regression relationship is displayed in **Figure 16**.

Relationships were developed between the difference between the "Wet" and "Combined" flow frequency curves and the logarithm of the drainage area associated with these two locations. An example of the regression analysis can be found in A linear relationship was developed at each exceedance probability. Using the drainage area at Halstad and the known "Wet" flow-frequency curve at Halstad these relationships could be used to determine the combined flow-frequency curves at Halstad. The WET and the combined 25-year and 50-year look-ahead curves at Halstad can be found in **Figure 17**, **Figure 18**, and **Figure 19**, respectively.

5.2 ANNUAL PEAK FLOW-FREQUENCY ANALYSIS – TRIBUTARIES

To build an adequate steady state HEC-RAS model ***(reference 8)*** for the project area it was necessary to develop flow-frequency curves based on the annual instantaneous peak flows for the Wild Rice Tributary, ND. Peak flows from the Wild Rice were derived from flows at the Abercrombie gage just upstream of the confluence. As indicated by **Table 17,** the observed streamflow record at Abercrombie extends back to 1933.

Table 17. Annual Instantaneous Streamflow Data for USGS Gage 05053000 Wild Rice River-ND near Abercrombie, ND

Water Year	Stream-flow (cfs)	Water Year	Stream-flow (cfs)	Water Year	Stream-flow (cfs)
1933	57.0	1959	222[6]	1985	1,210[6]
1934	15.0	1960	640[6]	1986	2,210[6]
1935	513	1961	36.0[6]	1987	701[6]
1936	415	1962	3,610[6]	1988	105[6]
1937	540	1963	1,460[6]	1989	7,150[6]
1938	318	1964	415[6]	1990	74.0[6]
1939	1,350	1965	2,820[6]	1991	410[6]
1940	300	1966	2,850[6]	1992	1,000[6]
1941	608	1967	2,050[6]	1993	3,630[6]
1942	579	1968	127[6]	1994	2,430[6]
1943	5,500	1969	9,540[6]	1995	3,730[6]
1944	956	1970	556[6]	1996	3,260[6]
1945	2,840	1971	508[6]	1997	9,470[6]
1946	2,320	1972	2,100[6]	1998	3,770[6]
1947	2,450[1]	1973	426[6]	1999	1,690[6]
1948	729	1974	630[6]	2000	676[6]
1949	650[2]	1975	3,500[6]	2001	9,320[6]
1950	2,300	1976	870[6]	2002	1,010[6]
1951	1,890	1977	91.0[6]	2003	2,250[6]
1952	5,400	1978	4,900[6]	2004	2,630[6]
1953	2,500	1979	6,000[6]	2005	2,810[6]
1954	800	1980	1,800[6]	2006	9,180[6]
1955	550[2]	1981	25.8[6]	2007	6,030[6]
1956	750	1982	1,550[6]	2008	1,480[6]
1957	408	1983	265[6]	2009	14,100[6]
1958	262[6]	1984	2,970[6]		

[2]Discharge is an Estimate
[6]Discharge is affected by Regulation or Diversion

A flow-frequency analysis was carried out using HEC-SSP (***reference 9***) for both the POR and the WET portion of the record (1942-2009) at Abercrombie. A weighted skew coefficient was used to carry out this analysis. The regional skew at Abercrombie was set at -0.23, based on the St. Paul District Army Corps. Of Engineers regional skew map (***reference 10***). The mean squared error associated with this skew is 0.125. The median plotting position was used.

Because of the short period of record, a "dry" curve cannot be generated for the peak flow record at Abercrombie so the method used at Fargo cannot be used to determine the 25-year and 50-year look-ahead curves. In order to generate these combined curves it was necessary to use the assumption that Abercrombie and Fargo are located in hydrologically similar areas. Based on this assumption the percent differences between the wet curve at Fargo and the combined curves at Fargo could be used to translate the wet curve at Abercrombie into the 25-year combined curve and the 50-year combined curve at Abercrombie. The analytically fit unregulated curves at Fargo were used for this purpose. **Table 18** lists the flow-frequency values and statistics (where generated) for the POR, WET and weighted combined curves. The corresponding POR, WET, 25-yr look-ahead and 50-yr look-ahead plots can be found in **Figure 20, Figure 21, Figure 22, and Figure 23**, respectively.

Table 18. Peak Annual Flow-Frequency Curves for the Wild Rice Tributary, ND

Exceed. Prob	Wild Rice Tributary, ND Annual Inst. Peaks, cfs			
	POR	Wet Period	Comb- 25 yr	Comb- 50 yr
0.99	30	46	36	27
0.9	180	248	184	120
0.5	1,196	1,459	1,193	825
0.2	3,508	3,983	3,524	2,766
0.1	5,852	6,415	5,818	4,808
0.05	8,705	9,283	8,571	7,334
0.02	13,250	13,716	12,844	11,300
0.01	17,264	17,538	16554	14,797
0.005	21,765	21,743	20,646	18,670
0.002	28,440	27,863	26,614	24,346
LPIII Statistics				
Years of Record	78	68		
Mean	3.037	3.126		
St. Dev.	0.594	0.555		
Adopted Skew	-0.413	-0.419		

5.3 FLOW-FREQUENCY ANALYSIS- COINCIDENT FLOWS-TRIBUTARIES

Coincidental peak flows from the Wild Rice Tributary, ND, Wild Rice Tributary, MN and the Buffalo River for corresponding peak flows on the Red River were determined and flow-frequency curves were developed for the POR, WET, and future conditions (25-year look-ahead and 50-year look-ahead). The values associated with these curves can be found in **Table 19**.

Table 19. Flow-Frequency Curves for Coincident Flows for Corresponding Peaks on the Red River

Combined Coincidental Flows												
Exceedance Frequency	Wild Rice River, MN USGS Gage 05064000 at Hendrum, MN			Buffalo River Reference Gage USGS Gage 05062000 NR Dilworth, MN				Wild Rice River, ND USGS Gage 05053000 NR Abercrombie, ND				
	Wet POR Period (cfs)	25 yr (cfs)	50 yr (cfs)	POR	Wet Period (cfs)	25 yr (cfs)	50 yr (cfs)	POR	Wet Period (cfs)	25 yr (cfs)	50 yr (cfs)
0.90	682	480	400		246	183	157		9	8	8
0.75	1,263	937	765		579	443	370		240	190	163
0.50	2,348	1,894	1,569	1,096	1,312	1,076	903	950	1,419	1,148	957
0.25	4,089	3,550	3,095		2,615	2,288	2,009		2,587	2,245	1,958
0.2	4,647	4,102	3,618	2,701	3,061	2,719	2,413	3,700	3,021	2,691	2,375
0.1	6,393	5,798	5,272	4,073	4,431	4,036	3,684	5,900	6,185	5,658	5,185
0.05	8,165	7,547	6,993	5,550	5,809	5,385	5,004	8,400	8,649	8,057	7,520
0.02	10,547	9,894	9,304	7,623	7,604	7,149	6,738	11,700	11,655	10,980	10,367
0.01	12,373	11,703	11,096	9,256	8,923	8,457	8,033	13,500	13,780	13,134	12,545
0.005	14,211	13,524	12,900	10,928	10,198	9,721	9,288	15,000	15,801	14,577	13,500
0.002	16,652	15,942	15,296	13,174	11,804	11,318	10,875	18,000	18,342	17,264	16,300

5.3.1 Coincident Flows from the Wild Rice Tributary, ND

Coincidental peak flows from the Wild Rice tributary for corresponding peak flows on the Red River at Fargo were derived from flows at the Abercrombie gage just upstream of the confluence with the Wild Rice River and the Red River (as is described in **Appendix A-1**). **Table 20** in **Appendix A-1** lists the coincident data flow series. Coincident flows at Abercrombie can be assumed to be representative of the flow record at the mouth of the Wild Rice River because of Abercrombie's close proximity to the confluence of the Red River and the Wild Rice River (ND).

The coincidental flow frequencies for the POR for the Wild Rice Tributary can be found in **Table 19.** The corresponding flow-frequency curve can be found in **Figure 24**.

The coincident flow record at Abercrombie is limited to 1933-2009. A graphical flow-frequency curve for the WET portion of the record was developed using the observed coincident flow record plotted using Weibull plotting positions. The values corresponding to the WET flow-frequency curve for the Wild Rice Tributary, ND can be found in **Table 19**. The corresponding flow-frequency curve is displayed in **Figure 25**.

Because of the short period of record, a "dry" curve cannot be generated for the coincident flow record at Abercrombie, so the method used at Fargo cannot be used to get the 25-year and 50-year look-ahead curves. To generate the combined curves, it was necessary to use the assumption that Abercrombie and Fargo are located in hydrologically similar areas. Based on this assumption the percent differences between the wet curve at Fargo and the combined curves at Fargo could be used to translate the wet curve at Abercrombie to the 25-year combined curve and the 50-year combined curve at Abercrombie. The graphically fit <u>regulated</u> curves at Fargo were used for this purpose. The values corresponding to the 25-year and 50-year look-ahead flow-frequency curves can be found in **Table 19**. The future scenario frequency curves are shown in **Figure 26** and **Figure 27**.

<u>5.3.2 Coincidental Flows from the Buffalo River Tributary</u>

Coincidental peak flows from the Buffalo River tributary for corresponding peak flows on the Red River at Fargo were derived from flows at USGS gage 0506200 at Dilworth, MN upstream of the confluence of the Buffalo River and the Red River. **Table 20** lists the coincident flow data series.

The flow-frequency curve for the POR at Dilworth was developed using the observed coincidental flows at Dilworth. The coincident flow record at Dilworth is limited to 1931-2009. A flow-frequency curve for the WET portion of the Record could be developed using the observed coincident flow record. It was found that a Log-Pearson Type III distribution fit the observed coincident flow record when plotted using the median plotting position.

Because Dilworth is located a significant distance upstream of the Buffalo River's confluence with the Red River of the North as can be seen in **Figure 28,** for both the POR and the WET flow frequency curves at Dilworth the curves had to be transferred to the mouth of the Buffalo River. This was done using the general relations methodology. This technique uses a drainage area ratio relating the drainage area at Dilworth to the drainage area associated with the confluence of the Buffalo River with the Red River. This drainage area ratio was raised to an exponent based on the logarithmic relationship between the POR flow-frequency curves at the Dilworth USGS gage and USGS gage 05061500 on the South Branch of the Buffalo River at Sabin and their associated drainage area ratio. The locations of these two USGS gages are displayed in **Figure 28.**

Table 21 contains the values used to transfer flows from Dilworth to the confluence of the Buffalo River with the Red River for both the POR and the WET flow-frequency curves.

Because of the short period of record, a "dry" curve cannot be generated for the coincident flow record at Dilworth so the method used at Fargo cannot be used to generate the 25-year and 50-year look-ahead curves. To generate the combined curves it was necessary to use the assumption that the confluence of the Buffalo River with the Red River and the Fargo gage are located in hydrologically similar areas. Based on this assumption the percent differences between the wet curve at Fargo and the combined curves at Fargo could be used to translate the wet curve at the mouth of the Buffalo River to the 25-year combined curve and the 50-year combined curves. Because an analytical curve had been used to fit the wet portion of the curve at Dilworth, the analytically fit unregulated curves at Fargo were used for this purpose. The values corresponding to the POR, 25-year and 50-year look-ahead flow-frequency curves can be found in **Table 19**. The WET and future scenario frequency curves are shown in **Figure 29, Figure 30, and Figure 31**.

Table 20. Coincidental Flows, based on the Mean daily flows recorded by USGS Gage 05062000 on the Buffalo River NR Dilworth, MN

Water Year	Coincidental Flow, cfs	Water Year	Coincidental Flow, cfs	Water Year	Coincidental Flow, cfs
1931	36	1961	64	1991	280
1932	276	1962	4,400	1992	385
1933	248	1963	511	1993	1,310
1934	374	1964	1,110	1994	971
1935	227	1965	2,950	1995	1,310
1936	1,160	1966	3,390	1996	2,350
1937	295	1967	783	1997	5,410
1938	277	1968	186	1998	4,680
1939	1,200	1969	2,850	1999	640
1940	500	1970	691	2000	1,620
1941	750	1971	175	2001	4,650
1942	264	1972	1,410	2002	1,000
1943	1,980	1973	125	2003	1,240
1944	486	1974	1,940	2004	1,400
1945	2,180	1975	10,900	2005	1,950
1946	1,050	1976	780	2006	4,420
1947	2,620	1977	38	2007	1,230
1948	950	1978	4,680	2008	2,130
1949	178	1979	3,240	2009	6,430
1950	2,600	1980	1,480		
1951	1,630	1981	926		
1952	1,650	1982	1,820		
1953	350	1983	205		
1954	67	1984	2,020		
1955	1,230	1985	1,930		
1956	1,670	1986	2,090		
1957	1,080	1987	820		
1958	999	1988	480		
1959	300	1989	2,780		
1960	1,050	1990	330		

Table 21. Buffalo River Flow Transfer from USGS gage at Dilworth to the Confluence of the Buffalo River with the Red.

% Chance Exceedance	USGS 05062000 Mainstem Buffalo R. Dilworth, MN Peak Discharge (cfs)	USGS 05061500 S Branch Buffalo R. Sabin, MN Peak Discharge (cfs)	Exponent[1]	POR		WET	
				Dilworth Coin. Peak Discharge (cfs)	Peak Discharge at the Confluence[2] (cfs)	Dilworth Coin. Peak Discharge (cfs)	Peak Discharge at the Confluence[2,3] (cfs)
0.2	23,492	16,155	0.49	11,954	13,174	10,710	11,804
0.5	18,022	12,754	0.45	9,990	10,928	9,322	10,198
1	14,443	10,439	0.42	8,508	9,256	8,202	8,923
2	11,309	8,342	0.40	7,044	7,623	7,027	7,604
5	7,793	5,895	0.37	5,162	5,550	5,403	5,809
10	5,567	4,282	0.34	3,805	4,073	4,140	4,431
20	3,679	2,867	0.33	2,532	2,701	2,869	3,061
50	1,630	1,274	0.32	1,028	1,096	1,231	1,312
80	702	533	0.36	352	378	430	462
90	447	330	0.40	187	202	227	246
95	306	220	0.43	107	117	128	140
99	148	99	0.53	34	38	39	43
	Dilworth	**Sabin**	**Buffalo R. Mouth**	[1] **Exponent (e) = Log ($Q_{Dilworth}/Q_{Sabin}$)/ Log ($DA_{Dilworth}/DA_{Sabin}$)**			
DA sq. mi	975	454	1,189	[2] $Q_{confluence} = Q_{Dilworth} * (DA_{Conf} / DA_{Dilworth})^e$			

[3] *The exponent 'e' was carried out to more significant figures in computation to minimize rounding error*

5.3.3 Coincident Flows from the Wild Rice Tributary, MN

Coincidental peak flows from the Wild Rice tributary, MN were found for corresponding peak flows on the Red River at Halstad. Coincidental Peaks were derived from flows at the Hendrum gage on the Wild Rice River upstream of the confluence of the Wild Rice River and the Red River. No transfer of coincidental flows at Hendrum to the mouth of the Wild Rice-MN is necessary because of Hendrum's close proximity to the confluence of the Wild Rice-MN with the Red River of the North. **Table 22** lists the annual coincident flow data series.

The coincident flow record at Hendrum is limited to 1944-2009. A flow-frequency curve for the WET portion of the record could be developed using the observed coincident flow record. It was found that a Log-Pearson Type III distribution fit the observed coincident flow record when plotted using the median plotting position. The values corresponding to the WET flow-frequency curve for the Wild Rice tributary, MN can be found in **Table 19**. The corresponding flow-frequency curve is displayed in **Figure 32**.

Table 22. Coincidental Flows based on the Mean Daily Flows recorded by USGS Gage 05064000 on the Wild Rice River- MN at Hendrum, MN

Water Year	Coincidental Flow	Water Year	Coincidental Flow
1944	2, 170	1987	1,200
1945	1,800	1988	850
1946	1,500	1989	4,900
1947	4,200	1990	652
1948	2,000	1991	233
1949	550	1992	1,400
1950	2,800	1993	3,630
1951	1,600	1994	2,600
1952	880	1995	2,400
1953	1,470	1996	5,460
1954	1,560	1997	8,980
1955	1,700	1998	6,240
1956	4,150	1999	3,580
1957	897	2000	8,010
1958	544	2001	7,100
1959	357	2002	6,170
1960	1,400	2003	1,770
1961	808	2004	4,770
1962	2,070	2005	3,480
1963	710	2006	5,500
1964	2,570	2007	4,970
1965	4,340	2008	2,840
1966	3,560	2009	8,530
1967	2,960		
1968	273		
1969	3,120		
1970	2,880		
1971	850		
1972	2,800		
1973	980		
1974	5,210		
1975	6,720		
1976	2,050		
1977	92		
1978	9,110		
1979	7,600		
1980	1,770		
1981	509		
1982	1,500		
1983	2,090		
1984	2,100		
1985	4,370		
1986	3,800		

Because of the short period of record, a "dry" curve cannot be generated for the coincident flow record for the Wild Rice Tributary, MN so the method used at Fargo cannot be used to get the 25-year and 50-year look-ahead curves. To generate the combined curves, it was necessary to use the assumption that Hendrum and Fargo are located in hydrologically similar areas. Based on this assumption the percent differences between the wet curve at Fargo and the combined curves at Fargo could be used to translate the coincident wet curve at Hendrum to the 25-year combined curve and the 50-year combined curve coincident curve at Hendrum. The analytically fit unregulated curves at Fargo were used for this purpose. The values corresponding to the 25-year and 50-year look-ahead flow-frequency curves can be found in **Table 19**. The future scenario frequency curves are shown in **Figure 33** and **Figure 34**.

5.4 FLOW-FREQUENCY ANALYSIS- RED RIVER REACH BETWEEN GRAND FORKS & HICKSON

As described in **Section 4.7 of Appendix A-1** discharge-frequencies for this reach were based primarily on interpolations between adopted discharge-frequencies at Fargo and Hickson. It also incorporated the coincidental flow-frequencies from the Wild Rice River, ND, Wild Rice River, MN and the Buffalo Rivers. Interpolation was carried out for the POR, WET, and Future conditions (25-year look-ahead and 50-year look-ahead).

Flows were estimated between Fargo and Halstad using a drainage area ratio exponent between Halstad and Fargo as shown in **Table 23**. Flows upstream and downstream of the Sheyenne River were based on the generalized exponent. For the reach between Fargo and Hickson flows were varied only at locations upstream and downstream of the Wild Rice River, ND based on its corresponding coincidental flow. The resulting summaries of discharge-frequencies for the designated locations along the Red for the POR, WET, 25-year look-ahead period and 50-year look-ahead period can be found in **Table 24** through **Table 27**. **Figure 35** through **Figure 38** display the adopted POR, WET and combined discharge-frequency curves for designated locations on the Red.

The tables below indicate that the "Wet" scenario produces lower discharges than the "Period of Record Analysis" for the 0.2% exceedance frequency. This is because there is less variability within the flow record if you isolate the "Wet" period because you are now working with a homogenous flow record. Because there is less variability in the flows that are being considered, the standard deviation associated with the data set is smaller and thus one would expect the 0.2% event to deviate less from the series of observed flows for the WET period than you would when using the POR for analysis. Because there was so much variability in the POR flows due to the heterogeneity of the record one had to be excessively conservative in estimating the 0.2% event to account for this variability.

At Grand Forks, the WET analysis produces a flow frequency curve that reflects lower discharges than the POR analysis for events less frequent than the 10% event. Thus, according to the new hydrology adopted for this study the design level of protection for the Grand Forks flood Control Project is extremely conservative.

Table 23. Drainage Area Exponent for Red River reach between Fargo and Halstad

		Exceedance Frequencies, %						
n- values	50	20	10	5	2	1	0.5	0.2
POR	0.653	0.487	0.383	0.320	0.308	0.365	0.273	0.059
WET	0.602	0.483	0.400	0.397	0.392	0.410	0.272	0.167
25-yr	0.778	0.512	0.461	0.443	0.434	0.444	0.355	0.233
50-yr	0.927	0.621	0.526	0.493	0.478	0.479	0.435	0.297

Table 24. Summary Table Red River Flow-Frequencies – POR With Dams, Annual Instantaneous Peak Discharge Frequency

Location	POR DISCHARGE-FREQUENCY, cfs								
	Drainage Area Sq mi	Exceedance Frequency %							
		50	20	10	5	2	1	0.5	0.2
Grand Forks	**20,015**	**17,000**	**35,300**	**50,500**	**67,300**	**91,700**	**112,000**	**134,000**	**165,000**
u/s Red Lake R	16,215	11,090	24,600	36,100	48,900	67,600	83,700	100,000	124,000
Halstad	**13,755**	**9,850**	**20,700**	**29,800**	**39,900**	**54,600**	**66,900**	**80,200**	**99,200**
d/s Wild Rice R	13,735	9,831	20,672	29,767	39,863	54,538	66,829	80,136	99,183
Wild Rice R, MN coincidental	**1,650**	**2,348**	**4,650**	**6,395**	**8,162**	**10,529**	**12,335**	**14,147**	**16,544**
u/s Wild Rice R, MN	12,085	7,483	16,022	23,372	31,701	44,009	54,494	65,989	82,639
d/s Elm R	12,055	7,471	16,003	23,350	31,676	43,967	54,444	65,945	82,627
u/s Elm R	11,655	7,308	15,753	23,050	31,335	43,393	53,777	65,339	82,461
d/s Buffalo R	11,305	7,164	15,530	22,782	31,031	42,881	53,181	64,797	82,312
Buffalo R coincidental	**1,190**	**1,096**	**2,701**	**4,073**	**5,550**	**7,623**	**9,256**	**10,928**	**13,174**
u/s Buffalo R	10,115	6,068	12,829	18,709	25,481	35,258	43,925	53,869	69,138
d/s Sheyenne R	9,905	5,986	12,704	18,559	25,310	34,971	43,590	53,561	69,052
u/s Sheyenne R	5,055	3,857	9,277	14,345	20,404	26,915	34,090	44,569	66,349
Fargo	**3,220**	**3,639**	**8,900**	**13,865**	**19,831**	**26,000**	**33,000**	**43,500**	**66,000**
d/s Drain 53	3,165	3,639	8,900	13,865	19,831	25,999	32,999	43,499	65,999
u/s Drain 53	3,135	3,639	8,900	13,865	19,831	25,999	32,999	43,499	65,998
d/s Wild Rice R, ND	3,080	3,638	8,900	13,864	19,830	25,999	32,998	43,498	65,997
Wild Rice R, ND coincidental	**1,640**	**950**	**3,700**	**5,900**	**8,400**	**11,700**	**13,500**	**15,000**	**18,000**
u/s Wild Rice R, ND	1,440	2,688	5,200	7,964	11,430	14,299	19,498	28,498	47,997
d/s Wolverton Cr	1,430	2,729	5,021	7,861	11,321	13,639	18,993	28,504	46,881
u/s Wolverton Cr	1,325	2,573	5,778	8,328	11,910	18,202	22,522	28,326	36,339
Hickson	**1,310**	**2,550**	**5,900**	**8,400**	**12,000**	**19,000**	**23,100**	**28,300**	**35,000**
Wahpeton	**1,020**	**2,280**	**4,720**	**6,690**	**8,550**	**10,950**	**13,300**	**16,000**	**19,600**

Table 25. Snmmary Table Red River Flow-Frequencies – WET With Dams, Annual Instantaneous Peak Discharge Frequency

Location	Drainage Area Sq mi	WET SCENARIO DISCHARGE-FREQUENCY, cfs									
		Exceedance Frequency %									
		50	25	20	10	5	2	1	0.5	0.2	
Grand Forks	**20,015**	**23,295**	**37,605**	**42,139**	**56,354**	**70,956**	**91,026**	**106,838**	**123,201**	**145, 675**	
u/s Red Lake R	16,215	17,385	26,905	27,739	41,954	52,556	66,926	78,538	89,201	104,675	
Halstad	**13,755**	**13,074**	**22,261**	**25,260**	**34,871**	**45,014**	**59,306**	**70,798**	**82,872**	**99,713**	
d/s Wild Rice R	13,735	13,051	22,232	25,225	34,830	44,962	59,238	70,714	82,806	99,665	
Wild Rice R, MN coincidental	**1,650**	**2,348**	**4,089**	**4,102**	**6,393**	**8,165**	**10,547**	**12,373**	**14,211**	**16,652**	
u/s Wild Rice R, MN	12,085	10,703	18,143	21,123	28,437	36,797	48,691	58,341	68,595	83,013	
d/s Elm R	12,055	10,687	18,123	21,097	28,409	36,761	48,644	58,281	68,549	82,978	
u/s Elm R	11,655	10,472	17,854	20,756	28,028	36,271	48,004	57,480	67,923	82,513	
d/s Buffalo R	11,305	10,282	17,614	20,452	27,688	35,834	47,433	56,765	67,361	82,095	
Buffalo R coincidental	**1,190**	**1,312**	**2,615**	**2,719**	**4,431**	**5,809**	**7,604**	**8,923**	**10,198**	**11,804**	
u/s Buffalo R	10,115	8,970	14,999	17,733	23,257	30,025	39,829	47,842	57,163	70,291	
d/s Sheyenne R	9,905	8,857	14,860	17,555	23,062	29,776	39,503	47,432	56,838	70,046	
u/s Sheyenne R	5,055	5,908	11,026	12,683	17,616	22,791	30,340	35,989	47,331	62,621	
Fargo	**3,220**	**5,600**	**10,600**	**12,150**	**17,000**	**22,000**	**29,300**	**34,700**	**46,200**	**61,700**	
d/s Drain 53	3,165	5,600	10,600	12,150	17,000	22,000	29,299	34,699	46,199	61,699	
u/s Drain 53	3,135	5,599	10,600	12,150	17,000	21,999	29,299	34,699	46,199	61,699	
d/s Wild Rice R, ND	3,080	5,599	10,600	12,150	16,999	21,999	29,298	34,698	46,198	61,698	
Wild Rice R, ND coincidental Abercrombie	**1,640**	**1,419**	**2,587**	**3,021**	**6,185**	**8,648**	**11,655**	**13,780**	**15,801**	**18,342**	
u/s Wild Rice R, ND	1,440	4,180	8,013	9,129	10,814	13,351	17,643	20,918	30,397	43,356	
d/s Wolverton Cr	1,430	4,166	7,899	8,952	10,791	13,453	17,872	21,196	30,252	42,385	
u/s Wolverton Cr	1,325	4,021	6,756	7,227	10,537	14,618	20,566	24,472	28,720	33,177	
Hickson	**1,310**	**4,000**	**6,600**	**7,000**	**10,500**	**14,000**	**19,000**	**22,000**	**28,500**	**37,000**	

Table 26. Summary Table Red River Flow-Frequencies – 25-Yr Look-Ahead With Dams, Annual Instantaneous Peak Discharge Frequency

Location	25-YR LOOK-AHEAD SCENARIO DISCHARGE-FREQUENCY, cfs									
	Drainage Area Sq mi	Exceedance Frequency, %								
		50	25	20	10	5	2	1	0.5	0.2
Grand Forks	20,015	20,684	34,694	39,157	53,213	67,723	87,782	103,682	120,244	143,205
u/s Red Lake R	16,215	14,774	23,994	24,757	38,813	49,323	63,682	75,382	86,244	102,205
Halstad	13,755	11,480	20,392	23,330	32,771	42,799	57,006	68,501	80,649	97,734
d/s Wild Rice R	13,735	11,454	20,359	23,295	32,727	42,744	56,934	68,413	80,566	97,668
Wild Rice R, MN coincidental (Hendrum)	1,650	1,894	3,550	4,102	5,798	7,547	9,894	11,703	13,524	15,942
u/s Wild Rice R, MN	12,085	9,560	16,809	19,193	26,929	35,197	47,040	56,710	67,042	81,726
d/s Elm R	12,055	9,542	16,785	19,169	26,898	35,158	46,989	56,647	66,983	81,679
u/s Elm R	11,655	9,294	16,471	18,841	26,483	34,636	46,306	55,805	66,186	81,040
d/s Buffalo R	11,305	9,076	16,192	18,549	26,114	34,171	45,697	55,054	65,474	80,467
Buffalo R coincidental (confluence)	1,190	1,076	2,288	2,719	4,036	5,385	7,149	8,457	9,721	11,317
u/s Buffalo R	10,115	8,000	13,904	15,830	22,078	28,786	38,548	46,597	55,753	69,150
d/s Sheyenne R	9,905	7,871	13,741	15,661	21,865	28,519	38,198	46,165	55,340	68,814
u/s Sheyenne R	5,055	4,664	9,426	11,102	16,038	21,163	28,521	34,246	43,595	58,846
Fargo	3,220	4,352	8,968	10,608	15,394	20,345	27,441	32,921	42,242	57,641
d/s Drain 53	3,165	4,352	8,968	10,608	15,394	20,345	27,440	32,920	42,241	57,640
u/s Drain 53	3,135	4,352	8,968	10,608	15,394	20,345	27,440	32,920	42,241	57,640
d/s Wild Rice R, ND	3,080	4,351	8,968	10,608	15,393	20,344	27,440	32,919	42,240	57,639
Wild Rice R, ND coincidental (Abercrombie)	1,640	1,148	2,245	2,691	5,658	8,057	10,980	13,134	14,577	17,264
u/s Wild Rice R, ND	1,440	3,203	6,723	7,917	9,735	12,287	16,460	19,785	27,663	40,375
d/s Wolverton Cr	1,430	3,198	6,636	7,772	9,722	12,388	16,680	20,055	27,549	39,492
u/s Wolverton Cr	1,325	3,147	5,753	6,349	9,577	13,547	19,288	23,242	26,339	31,093
Hickson	1,310	3,139	5,632	6,160	9,555	13,729	19,709	23,757	26,164	30,016

Table 27. Summary Table Red River Flow-Frequencies – 50-Yr Look-Ahead With Dams, Annual Instantaneous Peak Discharge Frequency

Location	Drainage Area Sq mi	50-YR LOOK-AHEAD SCENARIO DISCHARGE-FREQUENCY, cfs								
		Exceedance Frequency, %								
		50	25	20	10	5	2	1	0.5	0.2
Grand Forks	**20,015**	**18,679**	**32,287**	**36,666**	**50, 530**	**64,931**	**84,960**	**100,932**	**11,7667**	**141,059**
u/s Red Lake R	16,215	12,769	21,587	22,266	36,130	46,531	60,860	72,632	83,667	100,059
Halstad	**13,755**	**10,264**	**18,836**	**21,697**	**30,963**	**40,872**	**54,989**	**66,482**	**78,692**	**95,991**
d/s Wild Rice R	13,735	10,236	18,799	21,658	30,916	40,813	54,913	66,390	78,592	95,908
Wild Rice R, MN coincidental Hendrum	**1,650**	**1,569**	**3,095**	**3,618**	**5,272**	**6,993**	**9,304**	**11,096**	**12, 900**	**15,296**
u/s Wild Rice R, MN	12,085	8,667	15,704	18,040	25,644	33,820	45,609	55,294	65,692	80,612
d/s Elm R	12,055	8,647	15,677	18,012	25,610	33,779	45,555	55,228	65,621	80,553
u/s Elm R	11,655	8,381	15,321	17,638	25,160	33,222	44,826	54,343	64,665	79,750
d/s Buffalo R	11,305	8,147	15,007	17,308	24,759	32,727	44,178	53,556	63,812	79,032
Buffalo R coincidental (confluence)	**1,190**	**903**	**2,009**	**2,413**	**3,684**	**5,004**	**6,738**	**8,034**	**9,288**	**10,875**
u/s Buffalo R	10,115	7,244	12,998	14,895	21,075	27,723	37,440	45,522	54,524	68,157
d/s Sheyenne R	9,905	7,105	12,813	14,702	20,844	27,438	37,067	45,067	54,029	67,734
u/s Sheyenne R	5,055	3,807	8,106	9,681	14,633	19,699	26,882	32,664	40,317	55,478
Fargo	**3,220**	**3,506**	**7,630**	**9,161**	**13,965**	**18,855**	**25,764**	**31,304**	**38,787**	**54,034**
d/s Drain 53	3,165	3,506	7,630	9,027	13,965	18,855	25,763	31,303	38,786	54,033
u/s Drain 53	3,135	3,506	7,630	8,953	13,965	18,855	25,763	31,303	38,786	54,033
d/s Wild Rice R, ND	3,080	3,505	7,630	8,819	13,964	18,854	25,763	31,302	38,786	54,032
Wild Rice R, ND coincidental Abercrombie	**1,640**	**957**	**1,958**	**2,375**	**5,185**	**7,520**	**10,367**	**12,545**	**13,450**	**16,299**
u/s Wild Rice R, ND	1,440	2,548	5,672	6,444	8,779	11,334	15,396	18,757	25,336	37,733
d/s Wolverton Cr	1,430	2,548	5,605	6,358	8,774	11,434	15,609	19,019	25,243	36,927
u/s Wolverton Cr	1,325	2,550	4,925	5,485	8,718	12,582	18,134	22,123	24,258	29,236
Hickson	**1,310**	**2,550**	**4,831**	**5,366**	**8,710**	**12,762**	**18,543**	**22,626**	**24,116**	**28,246**

6. Balanced Hydrographs

The Corps developed balanced hydrographs at all pertinent computation points within the study area in support of the unsteady RAS model. These events are the 0.2-, 0.5-, 1-, 2-, and 10-percent exceedance frequency events for the POR, WET, 25-yr, and 50-yr look-ahead periods. To configure these synthetic events, flood volume duration frequency analyses provided the volume, for each duration, and specified frequency. The Corps HEC-1 model ***(reference 11)*** used this information along with the 2006 event as a pattern event to configure the balanced hydrographs. The pattern event helps establish the shape and timing of the hydrograph in regard to volume.

The spring 2006 flood event was selected as the pattern event for all balanced hydrographs developed for the Fargo-Moorhead Metro Study. This is consistent with the methodology used for the Wild Rice Study, ND, which also uses 2006 as the pattern event. At the time that hydrologists began work on the Fargo Moorhead Metro Study the USGS discharge measurements associated with 2009 spring flood event were still listed as estimates and the 2010 spring flood had not yet occurred. With 2009 and 2010 data unavailable, the next largest event in terms of peak magnitude and volume was 1997. In 1997 spring snowmelt was interrupted by a blizzard. The blizzard caused runoff to recess for a week before resuming. As a result of atypical hydro meteorological conditions, the 1997 event could not be used as a pattern event. The 2006 event was deemed to be most representative of a typical flood event in the Red River Basin.

The procedure involved two approaches; direct and indirect analysis. POR and WET period analyses at gaged locations employed direct analysis of the available data. Indirect analysis was employed for the ungaged locations as well as the 25-yr and 50-yr look-ahead conditions. This is because mean daily flow series are not available for a direct analysis for these conditions. Indirect analysis was also employed for the "coincidental" balanced hydrographs for the tributaries as direct analysis for this type of event is not possible.

6.1 Flood Volume Frequency Curves - Direct Analysis

The first step in developing the balanced hydrographs was to develop flood volume frequency relationships for the period of record at pertinent gaged stations on the Red River and its tributaries. This was done using observed mean daily flow data. The Hydrologic Engineering Center's Statistical Software Package (HEC-SSP) ***(reference 9)*** was used to compute the volume-duration frequency curves. In some cases the skew and standard deviation were manually modified so that frequency curves did not cross one another. This was done by plotting the lognormal of skew or standard deviation associated with each duration versus the lognormal of the mean associated with each duration and applying a linear regression. The resulting linear regression was utilized to smooth the skew and standard deviation for each duration. The period-of-record varied at each gage with some gages becoming active after 1942. For those gages that were active prior to 1942, the POR analysis used the total record that was available, whereas the WET analysis used the period since 1942. If the gages became active after 1942, the analysis used the record that was available. This information can be found in **Table 28**.

Table 28: Flood Volume Frequency Pertinent Information

LOCATION	PERIOD OF RECORD	PROGRAM USED	STATISTICS SMOOTHED?
Red River at Fargo, ND	1901-2009	HEC-SSP	Yes
Wild Rice River at Abercrombie, ND	1932-2009	HEC-SSP	Yes
Buffalo River at Dilworth, MN	1931-2009	HEC-SSP	Yes
Red River at Halstad, MN	1962-2009	HEC-SSP	Yes
Wild Rice River at Hendrum, MN	1944-2009	HEC-SSP	Yes
Red River at Hickson, ND	1942-2009	HEC-SSP	Yes
Red River at Amenia, ND	1947-2009	HEC-SSP	Yes

Flood volume-duration frequency curves were developed for main stem gaged flows at Halstad, Fargo and Hickson on the Red River. These curves can be found in **Figure 39**, **Figure 42**, and **Figure 44,** respectively. Flood volume-duration frequencies were also required for tributary gages. These were: Wild Rice River-ND at Abercrombie, Buffalo River at Dilworth, Wild Rice River-MN at Hendrum, and the Rush River at Amenia. These curves can be found in **Figure 40, Figure 41, Figure 43, and Figure 45,** respectively.

6.2 Flood Volume Frequency Curves- Indirect Analysis

6.2.1 Gaged Locations

As described above, flood volume frequency analysis for the POR and WET curve at gaged points of interest (Fargo, Hickson, and Halstad), were developed using direct analysis. In regard to the indirect analysis, annual instantaneous peak flood frequency relations were developed at these locations for the POR and WET, 25-year look-ahead and 50-year look-ahead periods as described in the preceding sections of this appendix. An annual mean daily peak flow frequency curve was also generated for the POR. The 1-day duration for the future period curves were determined by correlating the POR annual mean daily peak flow-frequency curve with the annual instantaneous peak flows curve (1-day duration = annual mean daily peak flow at that exceedance probability). This relation was assumed to also apply between instantaneous peak and mean daily peak, flow frequencies for the WET, 25-yr and 50-yr combined curves. To configure the other durations, the volume duration curves at other durations were derived by assuming the same proportional change in flow volume, for each duration, as for the POR and WET flood volume frequency curves.

6.2.2 Tributaries Coincident Flows

The unsteady RAS model also requires discharges and volumes from the intervening tributaries that contribute flow to the Main Stem. These are the significant tributaries in terms of flow and are presented as "coincidental" balanced hydrographs. This is to maintain consistency throughout the Main Stem with respect to the magnitude of the event for each duration and specified exceedance frequency. Coincident Flow-Frequency analyses for the POR, WET, 25-yr and 50-yr condition were done for each of these tributaries in the same manner as described in early sections of this Appendix.

To match with the Main Stem, coincidental balanced hydrographs were required for the Buffalo River, the Wild Rice River, MN, the Wild Rice River, ND, Upstream and Downstream of the Sheyenne River's confluence with the Red River, the Maple River and the Rush River. The Corps derived coincident flood volume frequency curves at these tributaries by assuming the same proportional change in flood volume, for each duration, as at the most hydrologically similar gaged station.

For the indirect analysis, the Corps developed both the instantaneous and annual mean daily peak flow-frequency curves at these gaged locations for the POR and WET portion of the period of record. The 1-day duration for the WET and future period coincident curves were determined by correlating the WET mean daily peak flow-frequency curve with the instantaneous peak flows curve for the POR period at these hydrologically similar gaged stations (1-day duration = annual mean daily peak flow at that exceedance probability). This relation was assumed to also apply between instantaneous peak and mean daily peak, flow frequencies for the WET, 25-yr and 50-yr combined curves. To configure the other durations, the volume duration curves at other durations were derived by assuming the same proportional change in flow volume, for each duration, as for the POR and WET flood volume frequency curves at the hydrologically similar gaged locations.

The hydrologically similar location identified for each point of interest and the method used to produce to the volume duration curve is listed in **Table 29**. A sample set of the coincident flow volume duration curves for the WET, 25-yr and 50-yr periods generated indirectly using the gaged location at Hendrum, ND which was used to develop the balanced hydrographs for the Wild Rice River, ND can be found in **Figure 46, Figure 47, and Figure 48**, respectively.

Table 29. Hydrologically similar location/ methodology used to produce balanced hydrographs.

Location	River	Volume Type	Hydrologically Similar Location used for generating Flood Volume Frequency Curve or alternate method used to obtain Balanced hydrograph
Gaged			
Halstad	Red River	Main Stem	Halstad
Fargo	Red River	Main Stem	Fargo
Hickson	Red River	Main Stem	Hickson
Hendrum	Wild Rice River, MN	Coincidental	Hendrum
Dilworth	Buffalo River	Coincidental	Dilworth
Abercrombie	Wild Rice River, ND	Coincidental	Abercrombie
Ungaged			
Red DS Wild Rice, MN	Red River	Main Stem	Halstad
Red River DS Buffalo River	Red River	Main Stem	Halstad
Red River DS of Sheyenne River	Red River	Main Stem	Halstad
Red River US of Sheyenne River	Red River	Main Stem	Fargo
Buffalo River at Mouth	Buffalo River	Coincidental	Dilworth
Sheyenne River at Mouth	Sheyenne River	Coincidental	Subtract: Red DS of Sheyenne River - Red US Sheyenne River
Sheyenne River DS of Rush River	Sheyenne River	Coincidental	-1 Day shift translation from Sheyenne River at Mouth
Rush River at Mouth	Rush River	Coincidental	Amenia
Sheyenne River US of Rush	Sheyenne River	Coincidental	Subtract: Sheyenne DS of Rush River - Rush River at Mouth
Sheyenne River DS of Maple River	Sheyenne River	Coincidental	-1 Day shift from Sheyenne River US of Rush River
Maple River at Mouth	Maple River	Coincidental	Dilworth
Sheyenne River US of Maple River	Sheyenne River	Coincidental	Subtract: Sheyenne DS of Maple River - Maple River at Mouth

6.3 Balanced Hydrographs

6.3.1 Gaged Based

After producing the volume duration curves as described above, the 1-day, 3-day, 7-day, 15-day, and 30-day values could be used to configure balanced hydrographs. Once these durations were estimated, they were inputted into HEC-1 (**reference 11**) to configure a hydrograph that reflects these volumes per duration, patterned after the 2006 event hydrograph at that location. All balanced hydrographs were smoothed using the graphical capabilities of HEC-DSSVue (**reference 12**).

A sample set of the balanced hydrographs for the WET, 25-yr and 50-yr periods generated using the indirect methodology of producing coincident flood volume duration curves for the gaged location at Hendrum, ND can be found in **Figure 49, Figure 50, and Figure 51**, respectively.

6.3.2 Sheyenne River

To determine coincidental hydrographs on the Sheyenne, the analysis began at the downstream end at the confluence with the Red River. The balanced hydrographs on the Red River upstream of the Sheyenne were subtracted from the balanced hydrographs downstream of the Sheyenne to arrive at the corresponding coincident balanced hydrographs on the Sheyenne at the confluence of the Sheyenne River and the Red River. This method hinges on the correct assumption of the Red River development of discharge-frequencies, upstream and downstream of the Sheyenne and the resulting development of balanced hydrographs at those locations.

To determine the coincident balanced hydrograph on the Sheyenne River just downstream of the confluence of the Rush River with the Sheyenne, DSSVue was used to shift the coincident balanced hydrograph at the confluence of the Sheyenne with the Red River back one day.

The coincident balanced hydrograph at the confluence of the Rush River with the Sheyenne River was determined using the gaged location on the Rush River at Armenia. Coincident flows for the Amenia gage with peaks at the Fargo gage on the Red River were determined for the WET portion of the period of record from 1947-2009. The coincident flow record at Amenia can be found in **Table 30**.

This coincidental flow record was used to generate a flow-frequency curve for the WET portion of the period of record at Amenia using a graphical fit. This curve was then translated to the mouth of the Rush River using a drainage area ratio. The percent difference between the regulated WET flow-frequency curve and combined curves at Fargo was used to translate the WET curve at Amenia into the 25-yr and 50-yr combined curves at Amenia. The corresponding combined coincidental flow-frequency values can be found in **Table 31.**

Table 30. Coincident Flows derived from Mean Daily Streamflows Recorded by USGS gage 05060500 on the Rush River at Amenia, ND

Amenia: Coincident with Peaks at Fargo			
Water Year	Flow (cfs)	Water Year	Flow (cfs)
1947	1,180	1985	4
1948	100	1986	48
1949	13	1987	269
1950	400	1988	1
1951	19	1989	95
1952	25	1990	1
1953	27	1991	3
1954	0	1992	13
1955	31	1993	61
1956	93	1994	33
1957	11	1995	147
1958	56	1996	199
1959	0	1997	1,450
1960	224	1998	127
1961	0	1999	750
1962	5	2000	4
1963	8	2001	429
1964	42	2002	30
1965	195	2003	110
1966	220	2004	308
1967	3	2005	238
1968	6	2006	425
1969	302	2007	7
1970	141	2008	9
1971	1	2009	670
1972	35		
1973	65		
1974	565		
1975	168		
1976	90		
1977	0		
1978	120		
1979	1,360		
1980	46		
1981	0		
1982	570		
1983	68		
1984	211		

Table 31. Coincidental Flow-Frequency Curves Developed for USGS gage 05060500 Site on the Rush River at Amenia, ND

Combined Coincidental Flows			
Exceed. Prob.	Amenia- Graphical Fit		
	Wet Flow (cfs)	25-yr Flow (cfs)	50-yr flow (cfs)
0.99	0	0	0
0.9	2	2	2
0.75	17	15	14
0.5	123	107	95
0.2	598	545	494
0.1	1,212	1,127	1,050
0.05	1,934	1,823	1,721
0.02	2,980	2,832	2,696
0.01	3,815	3,659	3,517
0.005	4,674	4,356	4,074
0.002	5,840	5,535	5,261

The coincident balanced hydrograph for the Sheyenne River Upstream of its confluence with the Rush River was determined by subtracting the balanced hydrograph at the confluence with the Rush River from the balanced hydrograph downstream of the confluence of the Rush River with the Sheyenne River. To determine the coincident balanced hydrograph on the Sheyenne just downstream of the confluence of the Maple River with the Sheyenne, DSSVue was used to shift the coincident balanced hydrograph just upstream of the Sheyenne River's confluence with the Rush River back one day.

The coincident balanced hydrograph at the mouth of the Maple River was determined by transferring the annual instantaneous flow-frequency peaks at Dilworth to the mouth of the Maple River by using a ratio of 1.276 based on drainage area. The process described in **Section 6.2.2** was then used to develop the coincident volume duration curve at the confluence of the Maple River with the Sheyenne River using Dilworth as the hydrologically similar gage point. After producing the volume duration curve as described above the 1-day, 3-day, 7-day, 15-day, and 30-day values could be used to configure balanced hydrograph at the mouth of the Maple River using HEC-1.

The coincident balanced hydrograph for the Sheyenne River Upstream of its confluence with the Maple River was determined by subtracting the balanced hydrograph at the confluence of the Sheyenne with the Maple River from the balanced hydrograph downstream of the confluence of the Maple River with the Sheyenne.

The balanced hydrographs generated using this methodology were used to determine the flow-frequency inputs for the unsteady RAS model by identifying the peak value off the balanced hydrographs generated for each exceedance probability for the WET, 25-year look-ahead and 50-year look-ahead curves. These values can be found in **Table 32, Table 33,** and **Table 34**. A sample set of the balanced hydrographs for the 100-yr Wet condition that demonstrate this process can be found in **Figure 52, Figure 53,** and **Figure 54**.

Table 32. Summary Table Sheyenne River Flow-Frequencies – WET With Dams, Annual Instantaneous Peak Discharge Frequency

Location	Drainage Area sq mi	WET SCENARIO DISCHARGE-FREQUENCY, cfs				
		Exceedance Frequency, %				
		10	2	1	0.5	0.2
Red R u/s Conf Sheyenne R	5,055	17,616	30,340	35,989	47,331	62,621
Sheyenne R at Conf w/ Red R	4,850	11,755	22,317	26,594	31,433	38,795
Rush R at Conf w/ Sheyenne R	172	1,212	2,980	3,815	4,674	5,840
Sheyenne R u/s Conf w/ Rush R	4, 611	11,291	21,207	25,183	29,712	36,649
Maple R at Conf w/ Sheyenne R	1,518	5,654	9,703	11,386	13,012	15,062
Sheyenne R u/s Conf Maple R	3,092	7,933	15,856	18,962	22,202	29,180
Red R d/s Conf Sheyenne R	11, 335	23,062	39,503	47,449	56,838	70,046

Table 33. Summary Table Sheyenne River Flow-Frequencies – 25-yr Look-ahead *With Dams*, Annual Instantaneous Peak Discharge Frequency

Location	Drainage Area sq mi	25-yr Look-ahead SCENARIO DISCHARGE-FREQUENCY, cfs				
		Exceedance Frequency, %				
		10	2	1	0.5	0.2
Red R u/s Conf Sheyenne R	5,055	16, 038	28,521	34, 246	43, 595	58,846
Sheyenne R at Conf w/ Red R	4,850	11,489	21,414	25,542	29,769	36,800
Rush R at Conf w/ Sheyenne R	172	1,127	2,832	3,659	4,356	5,535
Sheyenne R u/s Conf w/ Rush R	4, 611	11,058	20,359	24,189	28,165	34,766
Maple R at Conf w/ Sheyenne R	1,518	5,150	9,123	10,791	12,404	14,442
Sheyenne R u/s Conf Maple R	3,092	7,711	14,713	18,452	19,858	25,472
Red R d/s Conf Sheyenne R	11, 335	21,865	38,198	46, 165	55,340	68,814

Table 34. Summary Table Sheyenne River Flow-Frequencies – 50-yr Look-Ahead With Dams, Annual Instantaneous Peak Discharge Frequency

Location	50-yr Look-ahead SCENARIO DISCHARGE-FREQUENCY, cfs					
	Drainage Area Sq mi	Exceedance Frequency, %				
		10	2	1	0.5	0.2
Red R u/s Conf Sheyenne R	5,055	14633	26,882	32,664	40,317	55,478
Sheyenne R at Conf w/ Red R	4,850	11,104	20,557	24,973	28,811	34,391
Rush R at Conf w/ Sheyenne R	172	1,050	2,696	3,517	4,074	5,261
Sheyenne R u/s Conf w/ Rush R	4, 611	10,701	19,552	23,672	27,310	32,458
Maple R at Conf w/ Sheyenne R	1,518	4,701	8,597	10,250	11,851	13,877
Sheyenne R u/s Conf Maple R	3,092	7,460	14,092	17,244	19,573	24,431
Red R d/s Conf Sheyenne R	11, 335	20,844	37,067	45,067	54,029	67,734

6.3.3 Lower Bound of True Balanced Hydrograph Volumes

The coincident balanced hydrographs, derived using the methodology as described in the preceding sections for development of the tributary inputs, can only be considered as an initial starting point or "lower bound" as flood volume may be under-estimated due to the fact that the historic coincident peaks were on the rising or falling limb of the recorded hydrographs. This could lead to mean 3-day, mean 7-day, etc., flows that are higher than the "peak" coincident flow. Because ratios are used to decrease the "peak" coincident flow into the mean daily flow, mean 3-day flow, etc., the method does not take into account this possibility, and the balanced hydrographs have the potential to underestimate the true flow volumes. The HEC-RAS model initially used these hydrographs and then were modified or calibrated along with local flow along the reach to match downstream balanced hydrographs on the Main Stem. Modelers are aware of this issue and will be adjusting for this throughout the modeling process.

6.4 Unsteady vs. Steady RAS modeling Inputs

The peak discharge values at various exceedance probabilities will be different for the unsteady and steady RAS models for the coincident flows at the mouth of Sheyenne River. To determine the steady RAS coincident discharge-frequencies at the mouth of the Sheyenne, the flow-frequency discharges upstream and downstream of the confluence of the Sheyenne and the Red Rivers were subtracted from each other at each exceedance probability.

The Unsteady RAS model coincident flow-frequency values at the mouth of the Sheyenne River are based on the balanced hydrograph methodology described in **Section 6.3.2**. This methodology involves subtracting the balanced hydrographs upstream of the confluence with the Sheyenne from the balanced hydrographs downstream of the confluence at each exceedance probability to generate the balanced hydrographs at the mouth of the Sheyenne River at the various exceedance probabilities. The peak discharge at each frequency was then determined to be equivalent to the peak of the balanced hydrograph at for that frequency of event. These values are listed in **Table 32, Table 33, and Figure 34.**

These two methodologies won't produce the same discharge-frequencies. The difference in timing between the upstream and downstream hydrographs will produce a hydrograph at the confluence with a greater peak (using the methodology described in **Section 6.3.2** for the Unsteady-RAS model), then if one had simply subtracted the peaks associated with the upstream and downstream balanced hydrograph (for the steady RAS model). This is made clearer by **Figure 55**.

7. Confidence Intervals

Confidence Limit curves are sometimes referred to as error limit curves about the adopted Log-Pearson Type III discharge-probability function developed using the non-central t distribution. Confidence limit curves are used to define the discharge-exceedance probability function's uncertainty.

The Corps calculated ninety percent confidence interval, limit curves for the unregulated and regulated conditions at Fargo. This was done for each of the climate futures; WET, 25-, and 50-yr, look-ahead periods. Equivalent years of record for the WET period were based on the 68 years that were available for that period. The DRY period had 40 equivalent years. The Corps's Flood Damage Analysis program ***(HEC-FDA, reference 13)*** calculates the limit curves based on the equivalent number of years for each period and the three moments of the Log Pearson Type III statistical distribution.

The WET and Dry period curves can be calculated directly based on the actual number of years in their respective periods. The combined curves for the 25-yr and 50-yr periods had to be estimated. Initially, the Corps calculated limit curves based on equivalent years for the 25-yr and 50-yr look-ahead conditions by weighting the respective years with the probability that each component would occur, (i.e. WET & DRY). For the 25-yr future period, the WET equivalent years were given a weight of 0.8 and the corresponding DRY condition years were assigned a weight of 0.2. The Corps assigned the 50-yr future a weight of 0.65 and 0.35 respectively. This computation generated equivalent years of 62 and 58 for the 25- and 50-yr look-ahead periods, respectively. Previous analysis described in this report determined the three moments of each future period.

The 25- and 50-yr look-ahead periods were deemed to have as much uncertainty in the upper limit as the WET period. Therefore, an adjustment to the upper 0.05 limit was computed by adjusting the equivalent years of record until the 2 percent exceedance frequency limit flows were the same for all three conditions. This resulted in equivalent years of record equal to 59 and 52 for the 25-yr and 50-year look-ahead periods. This was done to match the upper limit 0.05 limit curve for the WET future as close as possible for each combined future condition. As can be seen in **Figure 56**, the combined curves have different slopes so there cannot be a perfect match. Therefore, the Corps selected the 2 percent exceedance frequency as the best match point that would render equivalent economic impact to the WET 0.05 limit curve. **Table 35** lists the adopted 0.05 limit curve flow values for each exceedance frequency and future condition.

Table 35. Five % Confidence Limits for Climate Future and Equivalent Years

5 % CONFIDENCE LIMIT FOR CLIMATE FUTURE AND EQUIVALENT YEARS			
Exceedance Frequency	WET 68 yrs Flow, cfs	25-yr 59 yrs Flow, cfs	50-yr 52 yrs Flow, cfs
0.002	108,987	113,187	117,406
0.004	90,904	93,588	96,382
0.010	69,566	70,558	71,764
0.020	55,163	55,081	55,283
0.040	42,296	41,375	40,801
0.100	27,620	26,003	24,802
0.200	18,257	16,465	15,122
0.300	13,457	11,720	10,437
0.500	8,078	6,601	5,556
0.700	4,843	3,693	2,924
0.800	3,552	2,593	1,974
0.900	2,302	1,576	1,134
0.950	1,599	1,034	708
0.990	789	454	281
0.999	342	170	92

8. References

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5. Department of Defense, U.S. Army Corps of Engineers, Hydrologic Engineering Center, ***"HEC-HMS, Hydrologic Modeling System", Version 2.2***, September 1998.

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13. Department of Defense, U.S. Army Corps of Engineers, Hydrologic Engineering Center, ***"HEC-FDA, Flood Damage Reduction Analysis",*** November 2008.

FIGURES

Figure 1. Boise de Sioux and Red River of the North

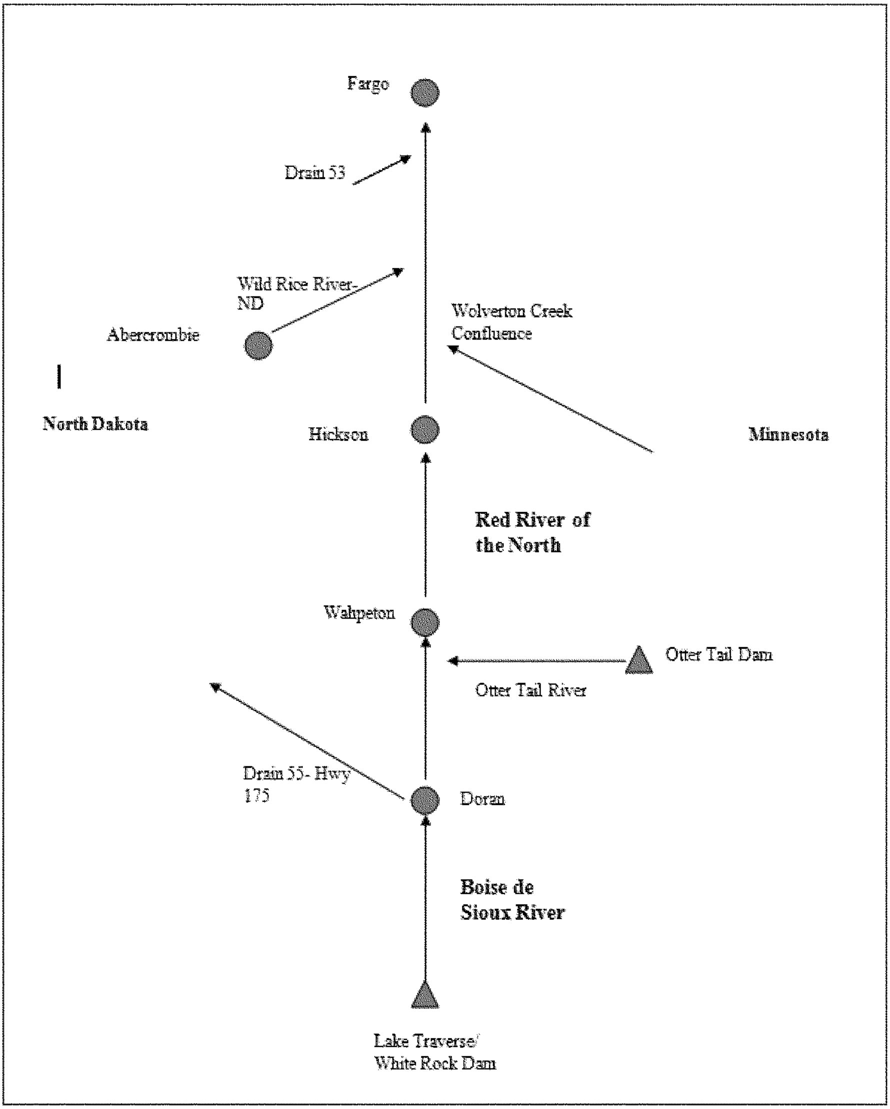


Figure 2. Red River Reach Fargo to Halstad

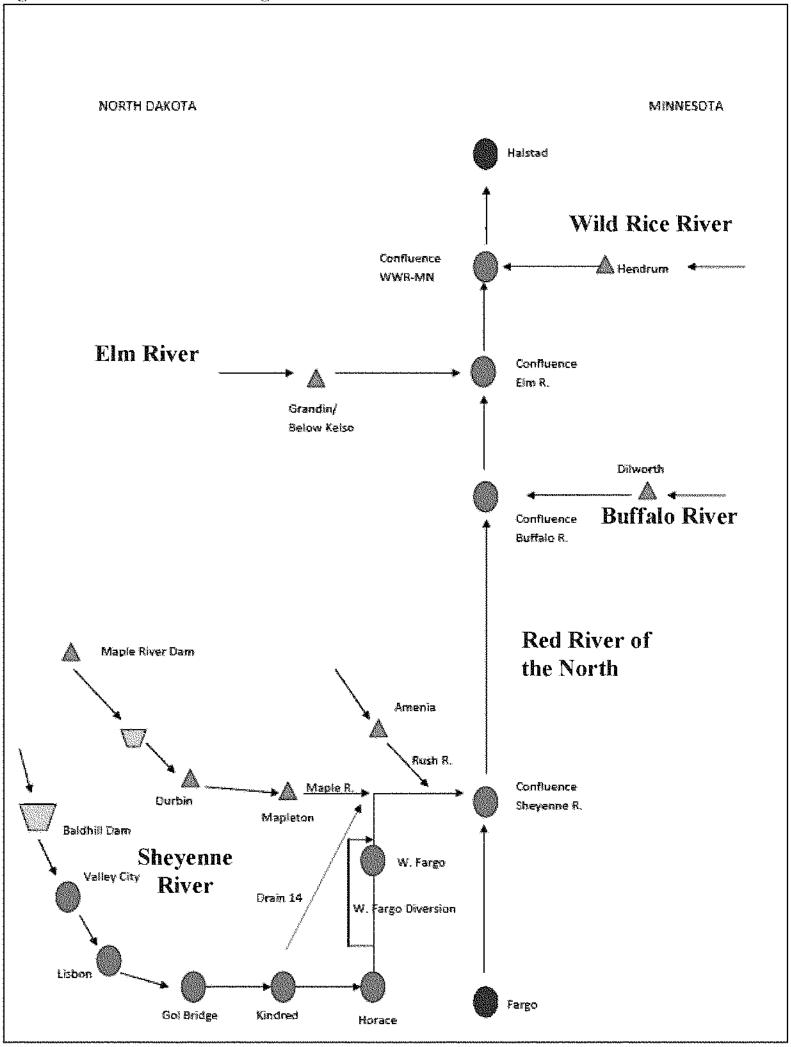


Figure 3. Red River Reach Halstad to Grand Forks

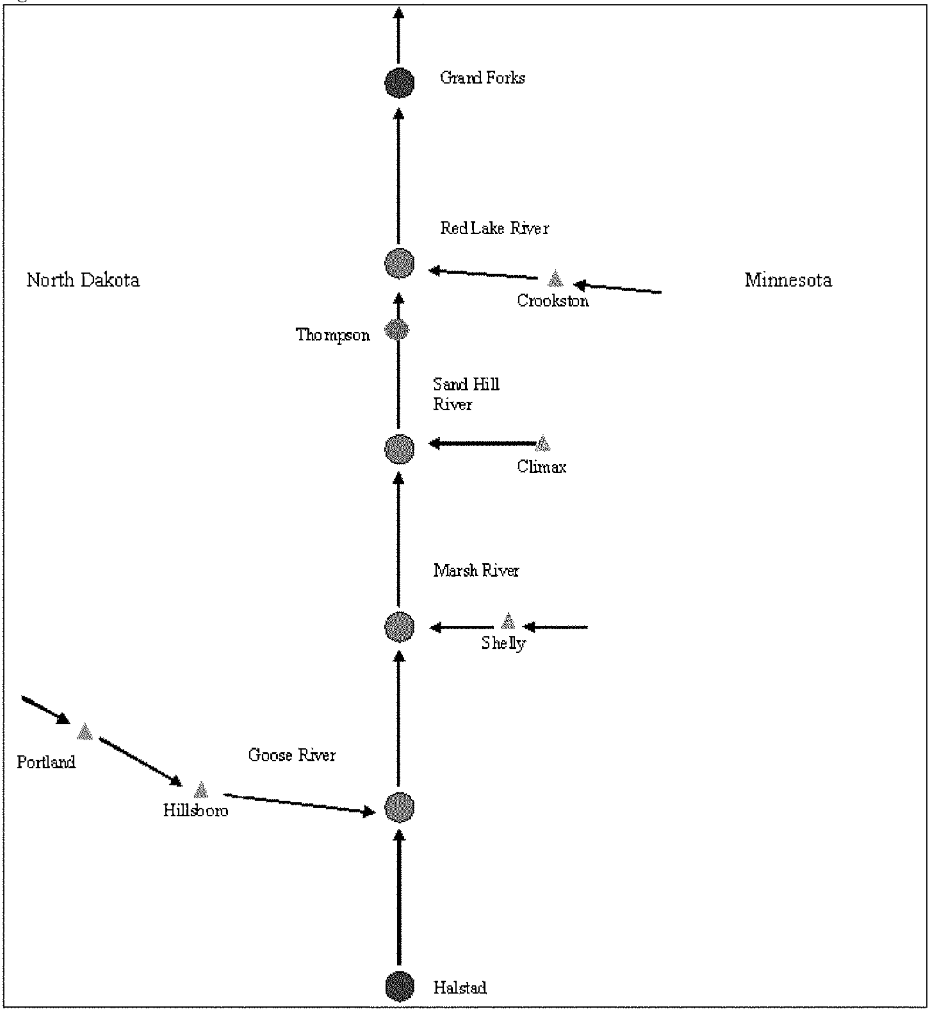


Figure 4- Red River at Grand Forks Peak Flow Frequency Curve- Full Period

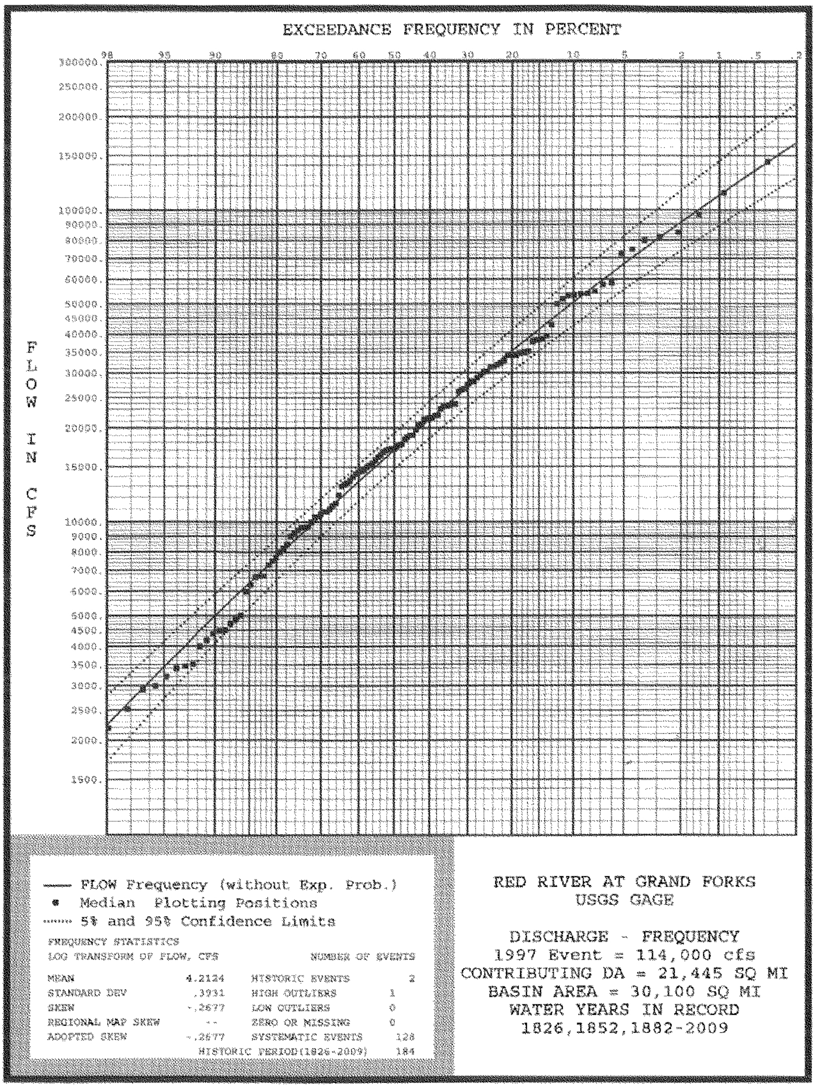


Figure 5- Red River at Halstad Peak Flow Frequency Curve- Full Period

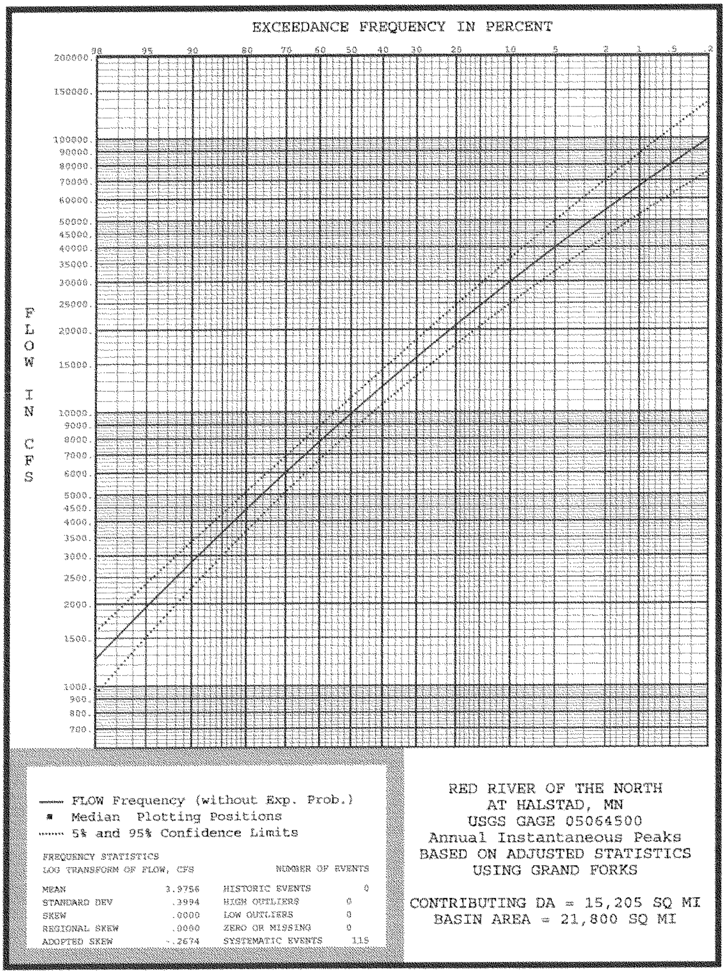
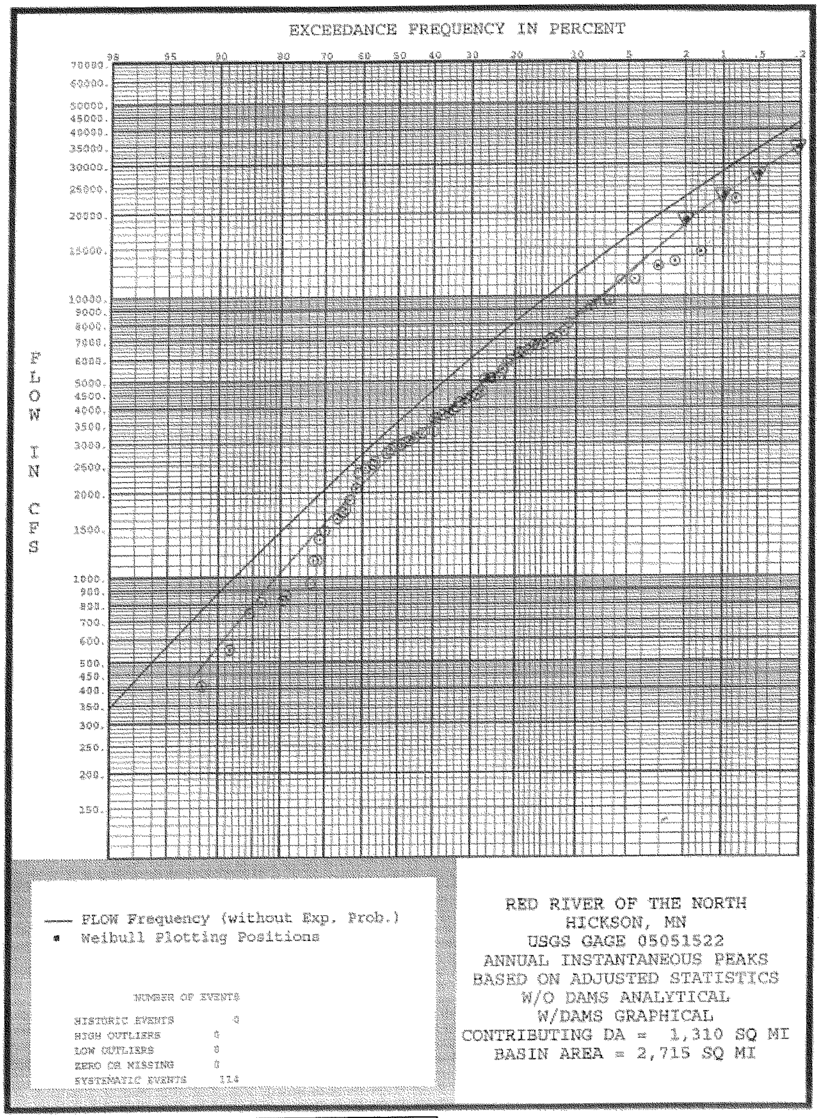


Figure 6- Red River at Hickson Peak Flow Frequency Curve- Full Period



Pencil Line = Graphical Flow Frequency Curve

Figure 7. Unregulated annual peak flows at Grand Forks

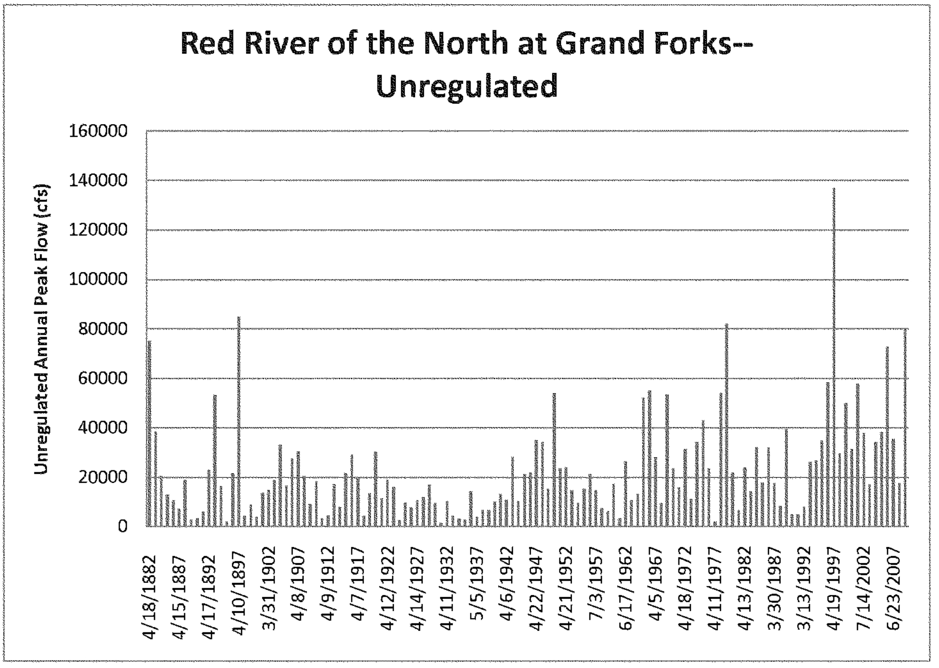


Figure 8. Change Point Analysis for Grand Forks, ND

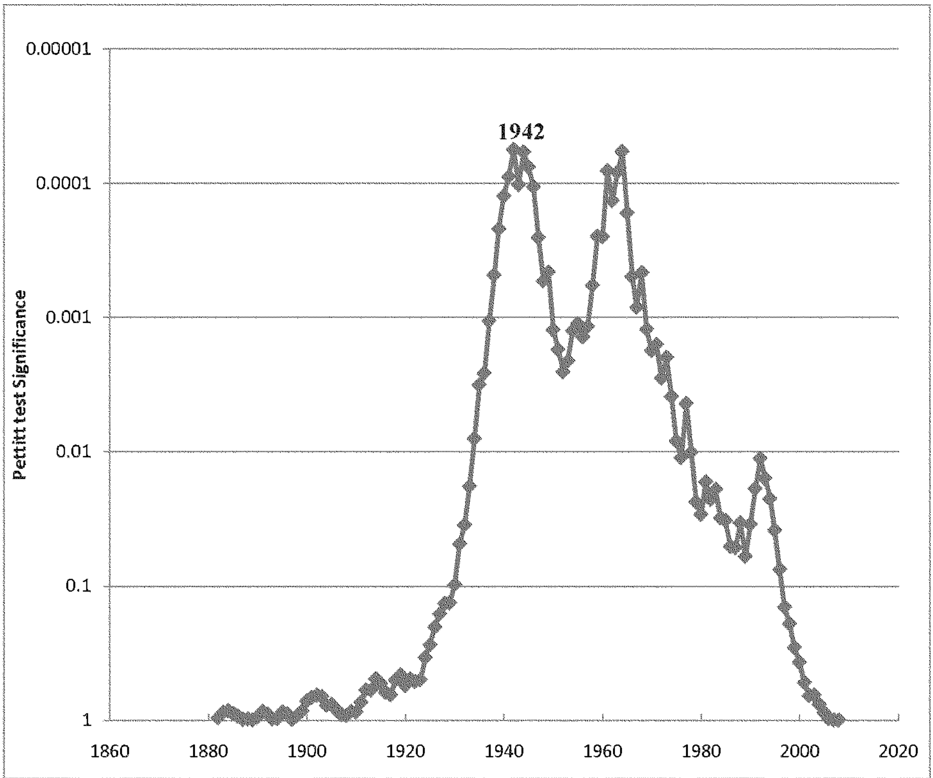


Figure 9. Red River of the North at Grand Forks- Flow Frequency Curves for Wet (1942-2009) and Dry Periods (1882-1941) with Median Plotting Positions

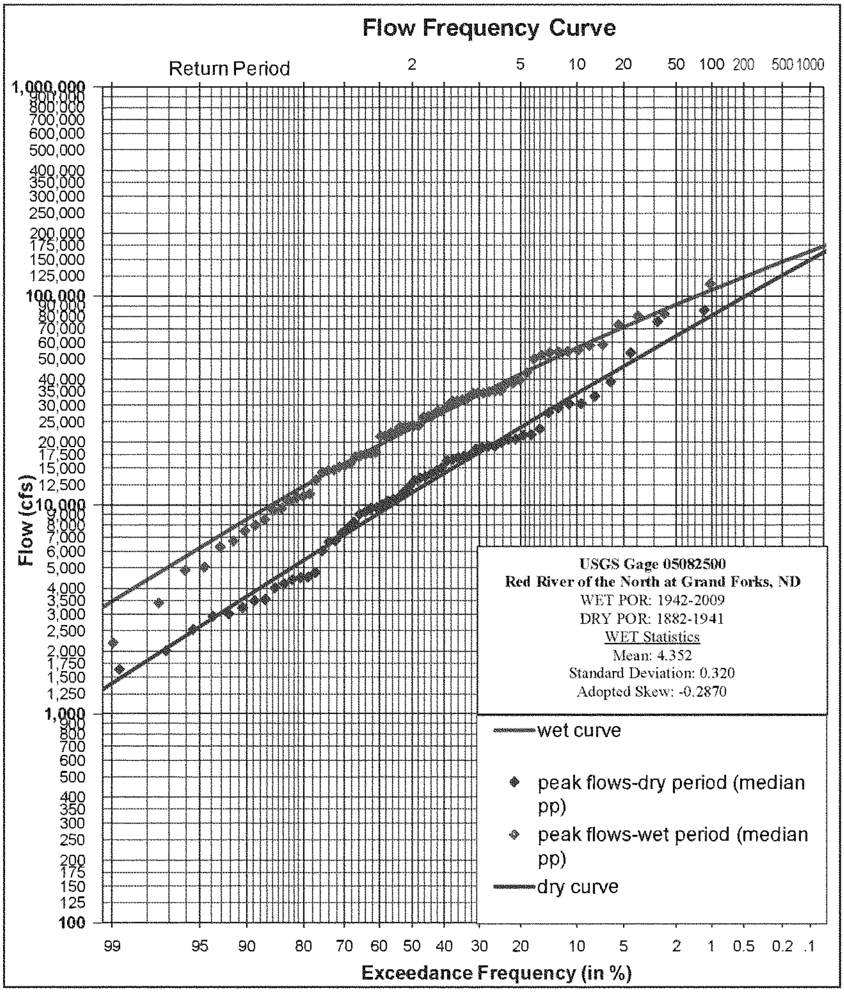


Figure 10. Grand Forks Peak Flow Frequency Curves for Wet and Dry Periods with 25-year Look Ahead Curve (0.8 wet and 0.2 dry weighting).

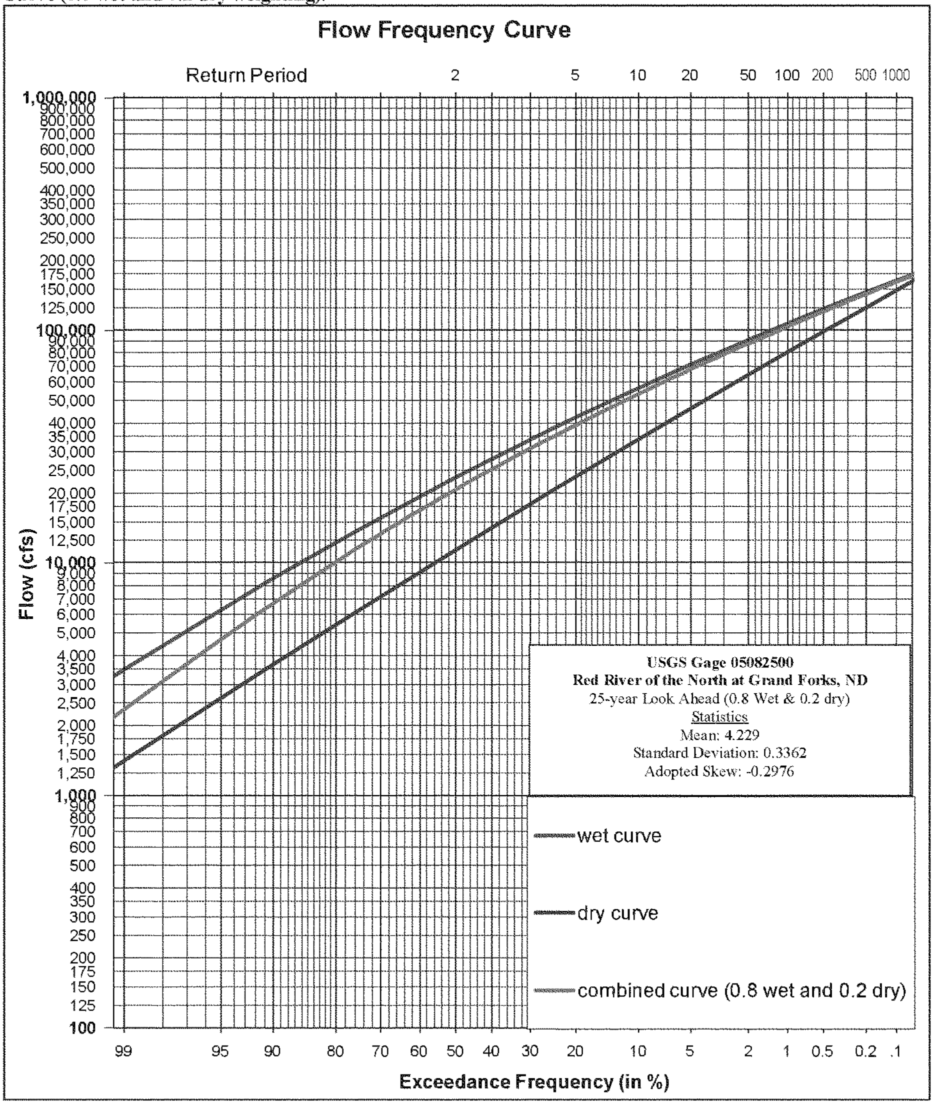


Figure 11. Grand Forks Peak Flow Frequency Curves for Wet and Dry Periods with 50-year Look Ahead Curve (0.65 wet and 0.35 dry weighting).

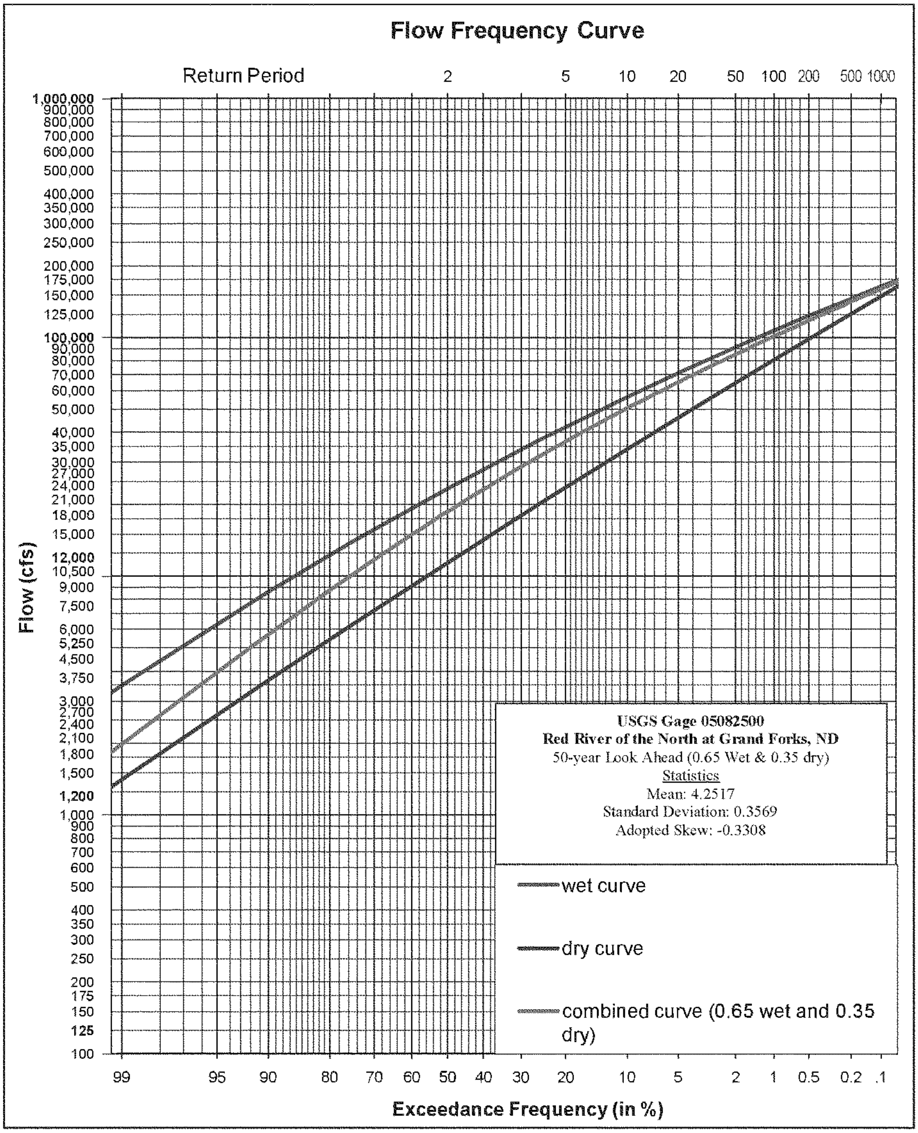


Figure 12. USGS Gage 05051522- Red River of the North at Hickson-Initial Peak Flow Frequency Curve for Wet Period (1942-2009) with Weibull plotting positions and synthetic events

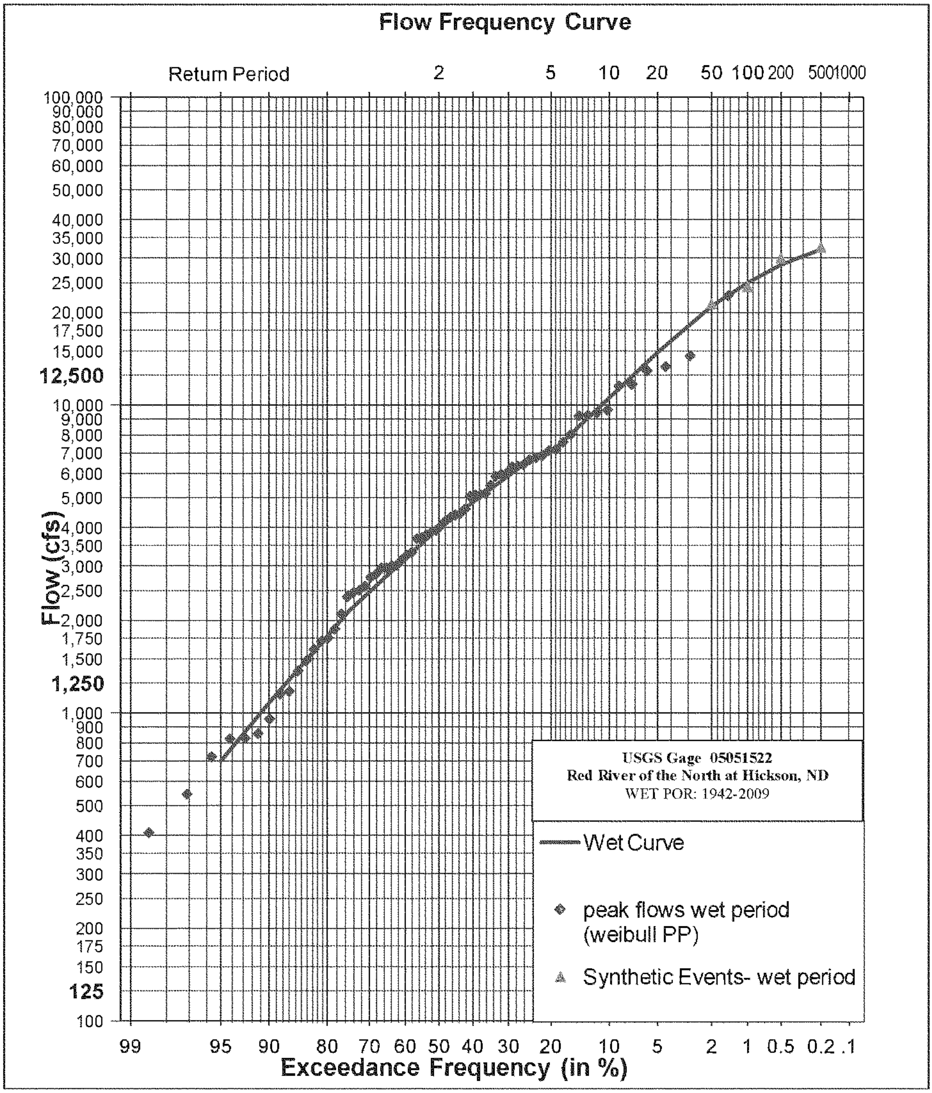


Figure 13. Hickson Peak Flow Frequency Curves for Wet Period and 25- year Look Ahead Curve (0.8 wet and 0.2 dry weighting)

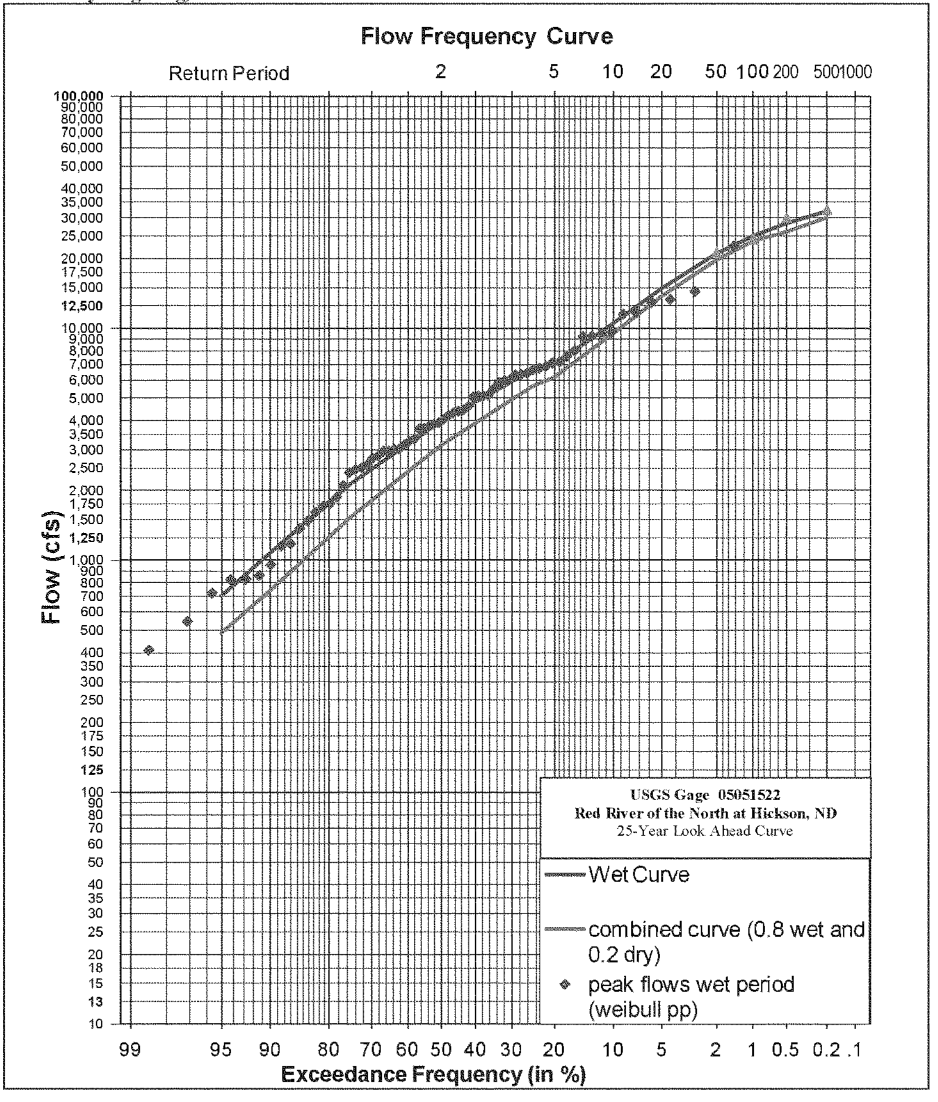


Figure 14. Hickson Peak Flow Frequency Curves for Wet and 50-year Look Ahead Curve (0.65 wet and 0.35 dry weighting).

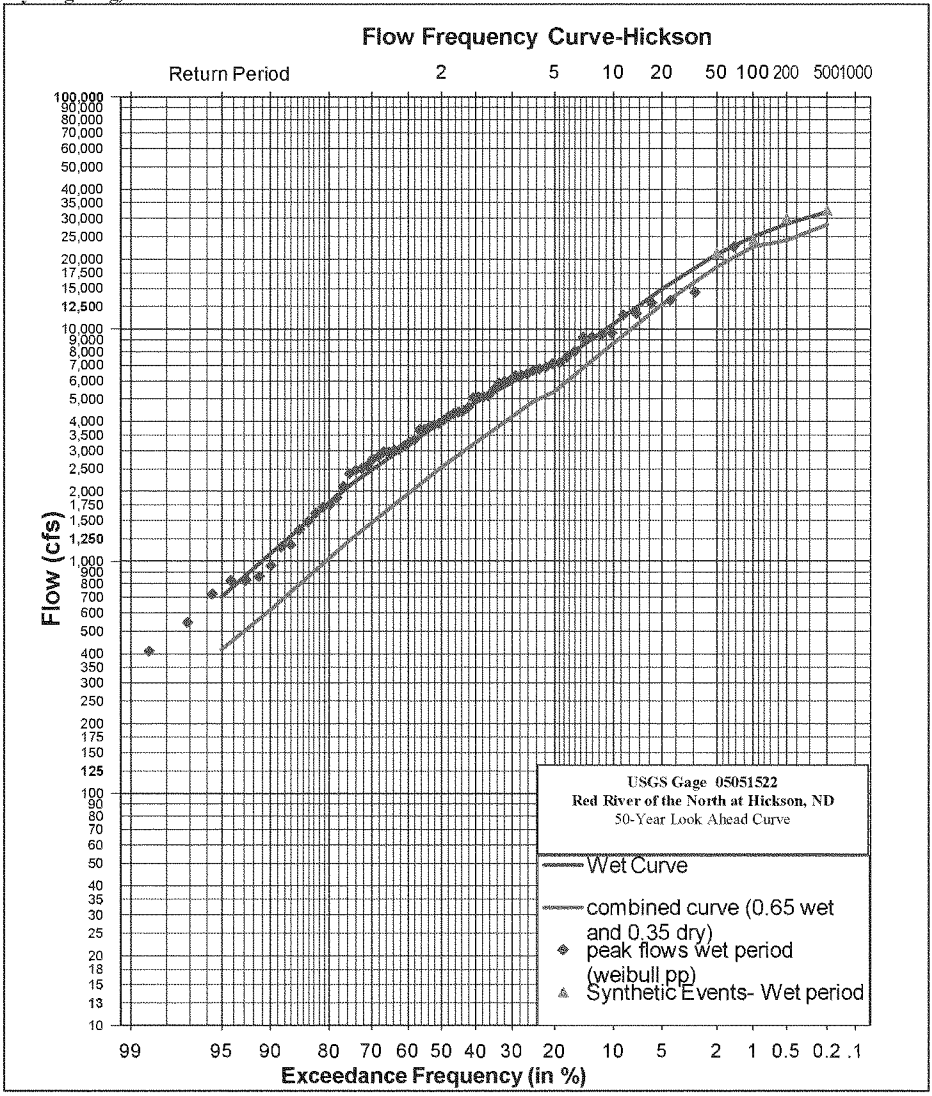


Figure 15. USGS Gage 05051522- Red River of the North at Hickson-Adopted Peak Flow Frequency Curve for Wet Period (1942-2009) with Weibull plotting positions

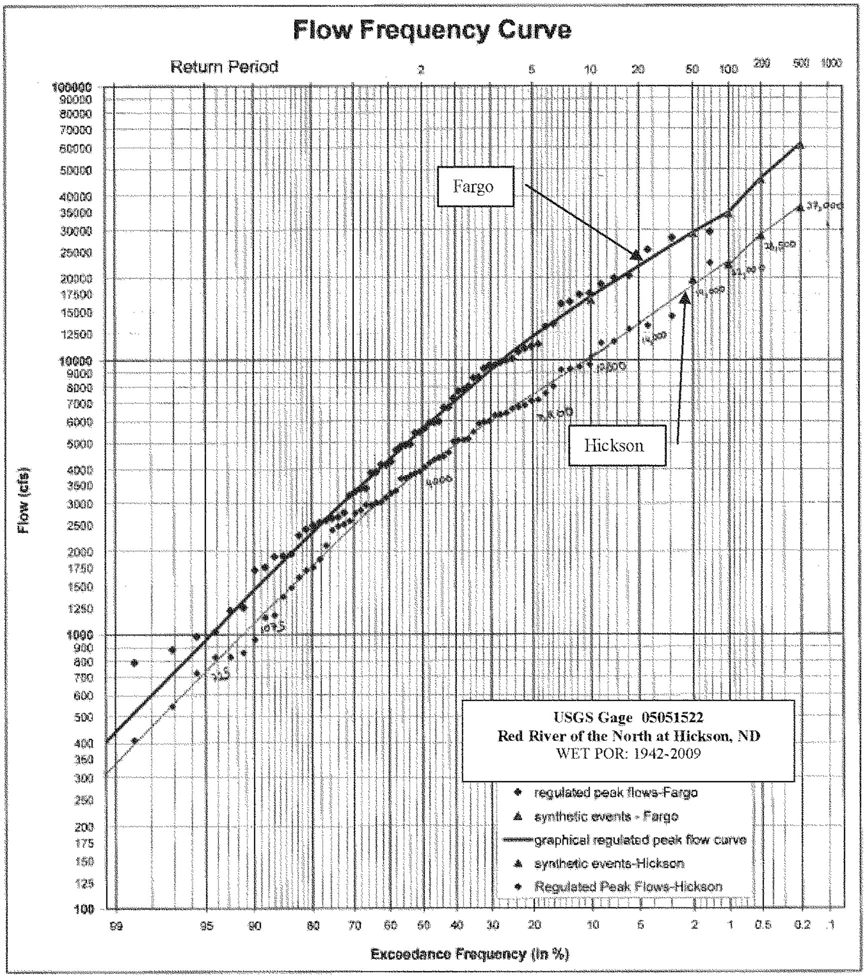


Figure 16. Example of Regression used to develop the combined curves at Halstad (5-year event, 25-year look-ahead period).

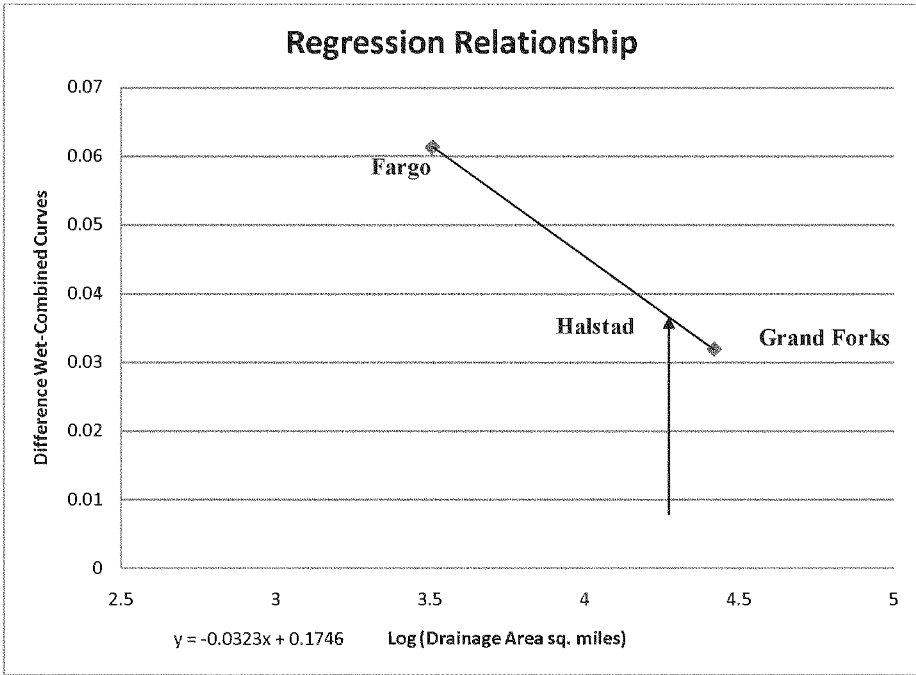


Figure 17. USGS gage 05064500 Red River of the North at Halstad, MN- Peak Flow Frequency Curve for Wet Period (1942-2009) with Median Plotting Position

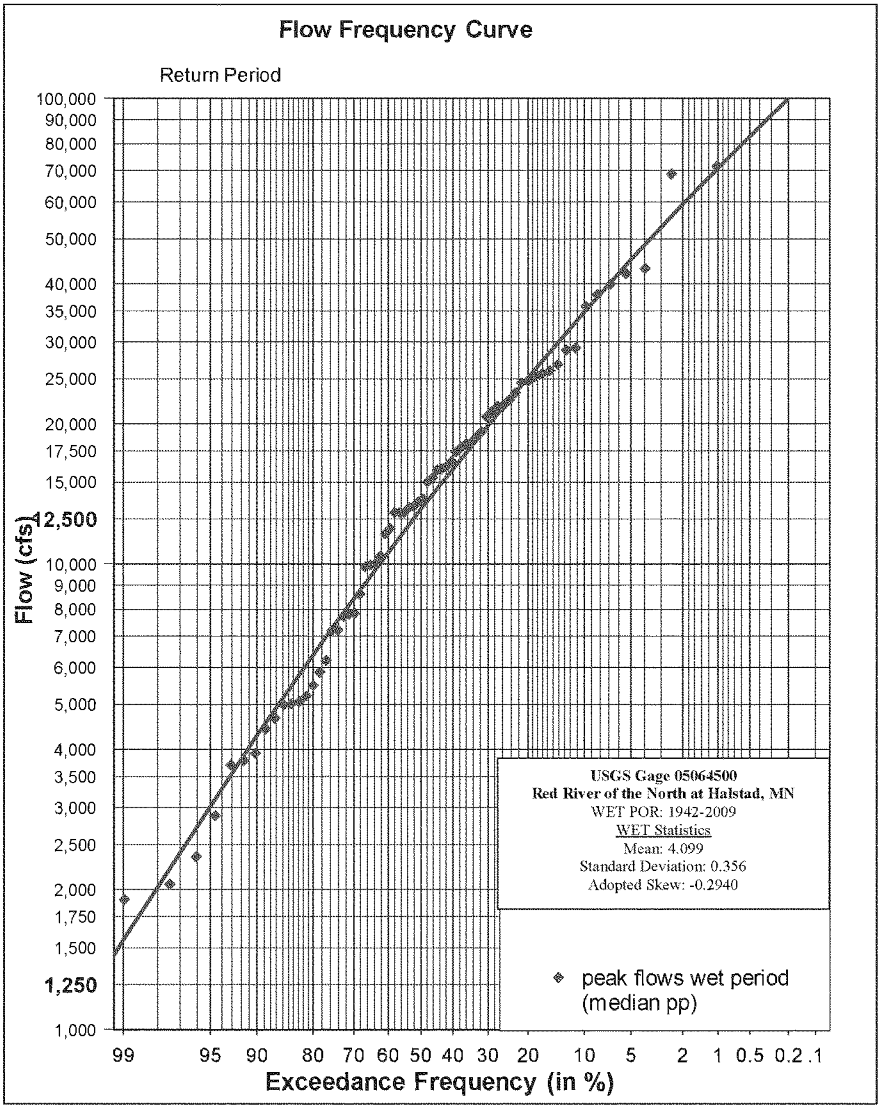


Figure 18. Halstad Peak Flow Frequency Curves for Wet and 25-year Look Ahead (0.8 wet and 0.2 dry weighting).

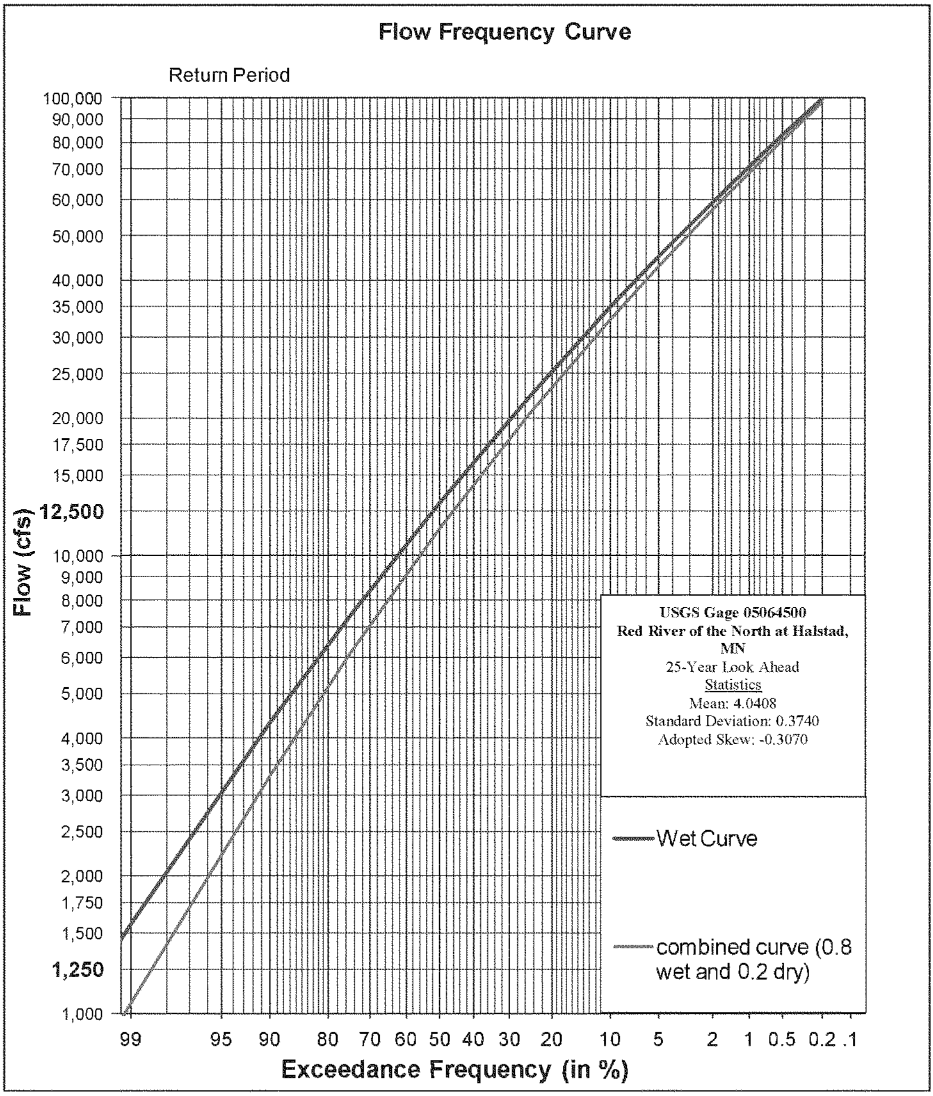


Figure 19. Halstad Peak Flow Frequency Curves for Wet and 50-year Look Ahead Curve (0.65 wet and 0.35 dry weighting).

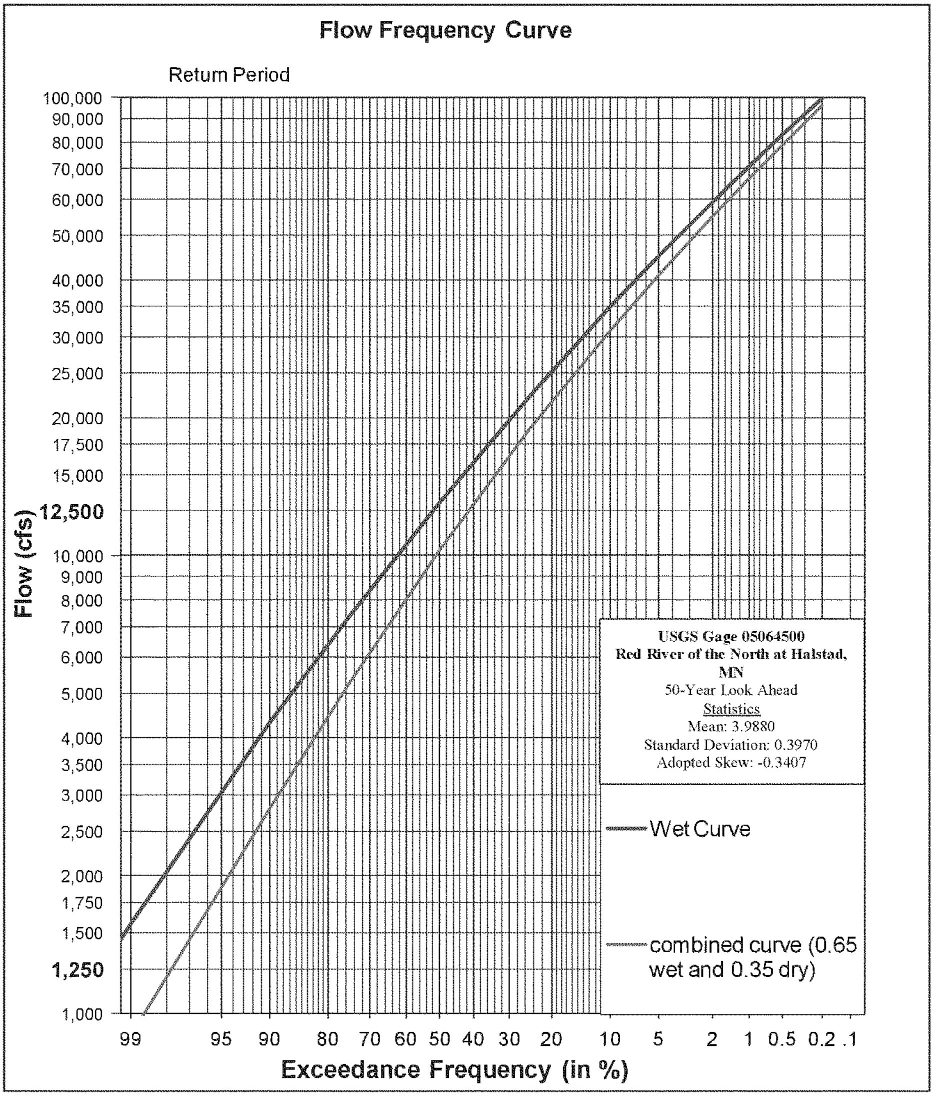


Figure 20. USGS Gage 05053000, Wild Rice River (ND) near Abercrombie, ND- Annual Instantaneous Peak Flow Frequency Curve- Full Period of Record.

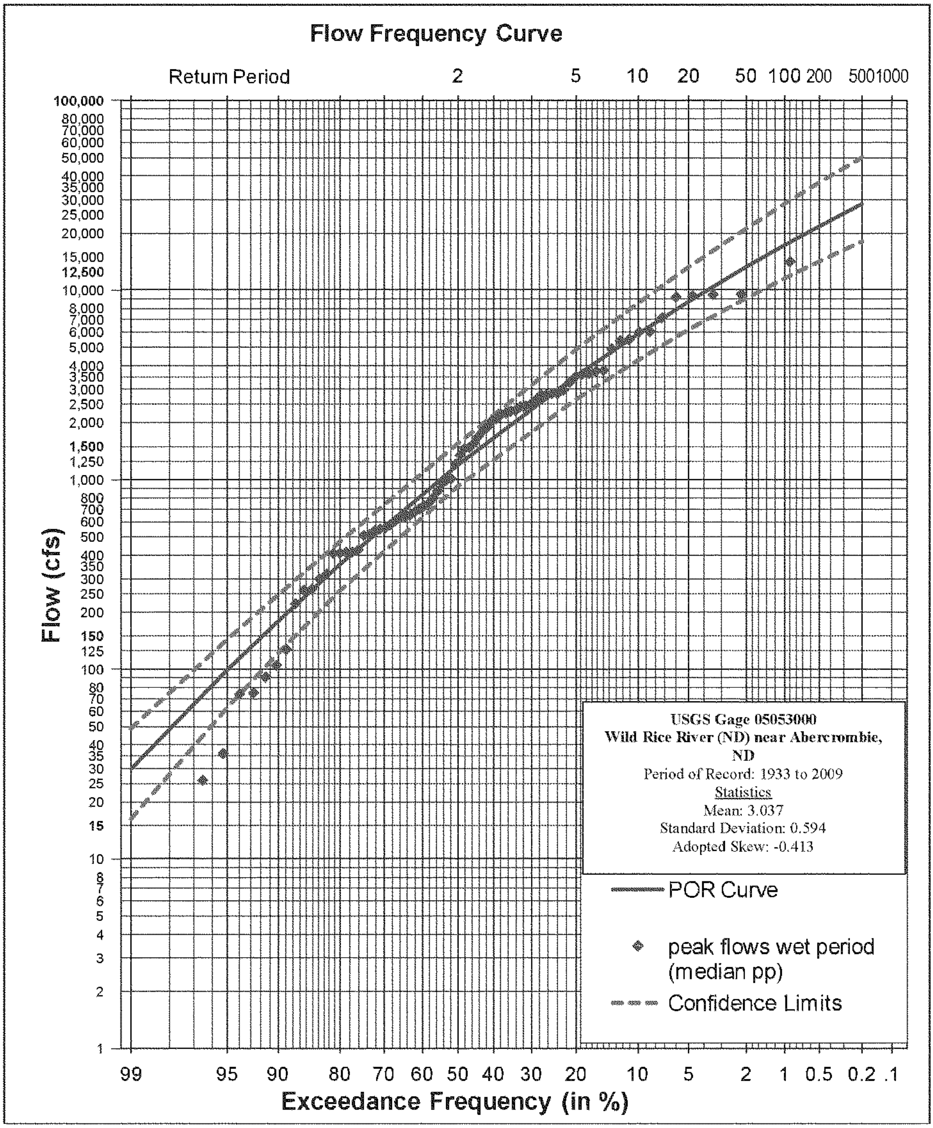


Figure 21. USGS Gage 05053000, Wild Rice River (ND) near Abercrombie, ND Peak Flow-frequency Curve for Wet Period (1942-2009) with median plotting positions.

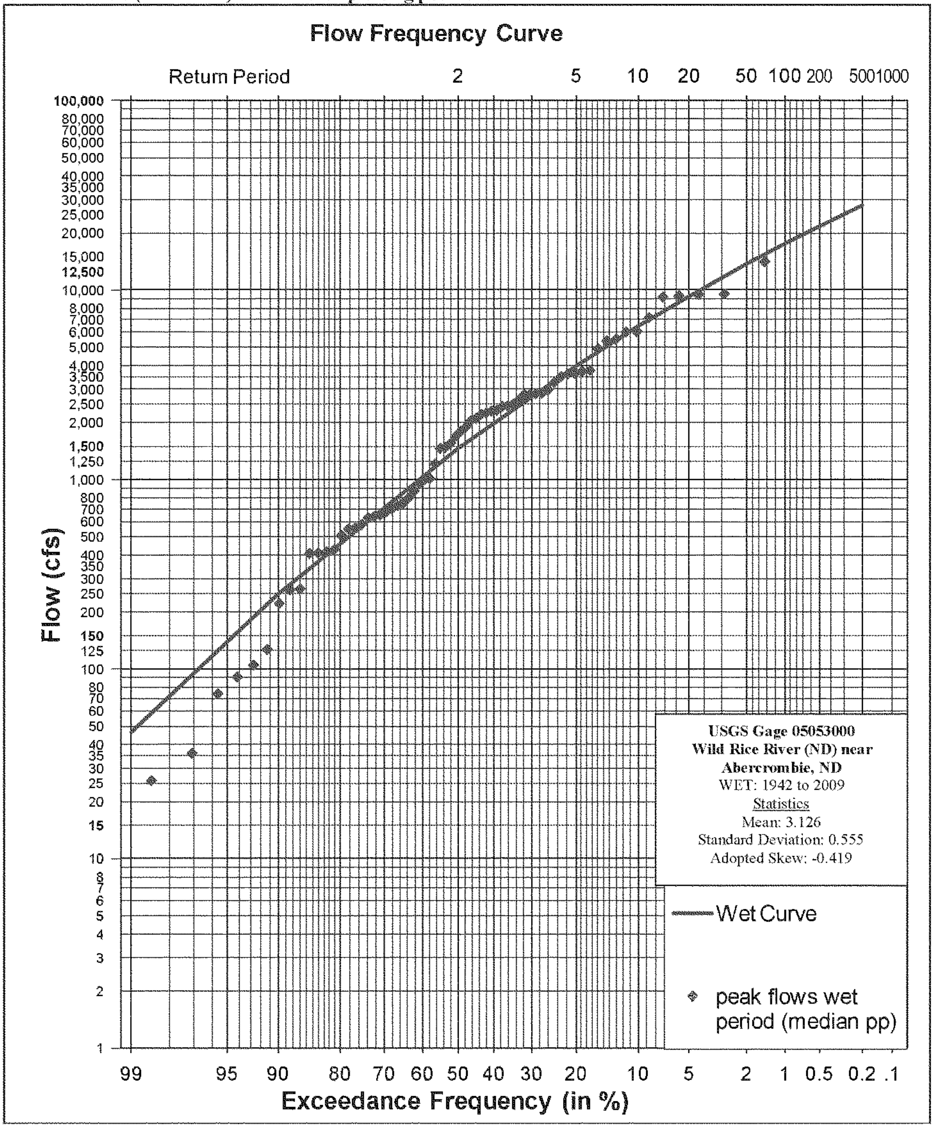


Figure 22. USGS Gage 05053000, Wild Rice River (ND) near Abercrombie, ND- Peak Flow Frequency Curves for Wet and 25-year Look Ahead Curve (0.8 wet and 0.2 dry weighting)

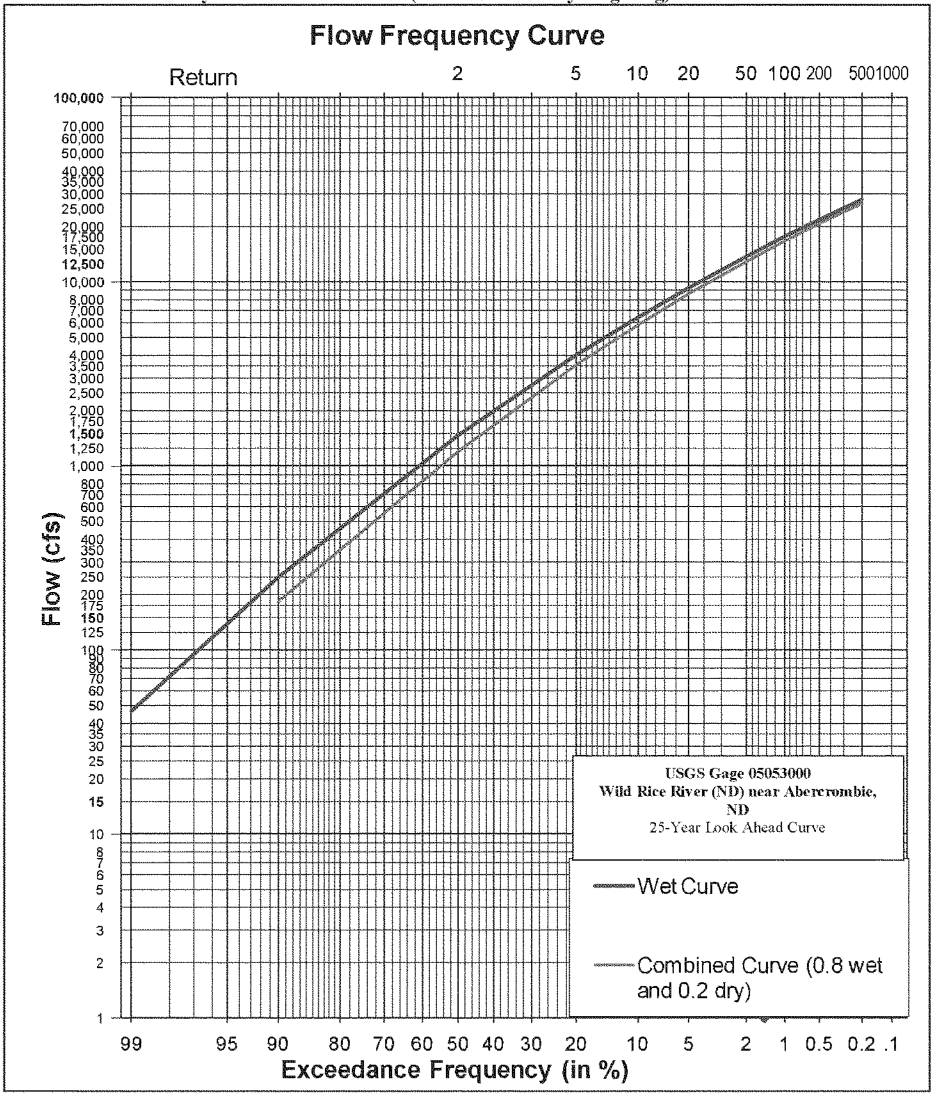


Figure 23. USGS Gage 05053000, Wild Rice River (ND) near Abercrombie, ND- Peak Flow frequency curves for Wet and 50-year Look-Ahead Curves (0.65 wet and 0.35 dry weighting).

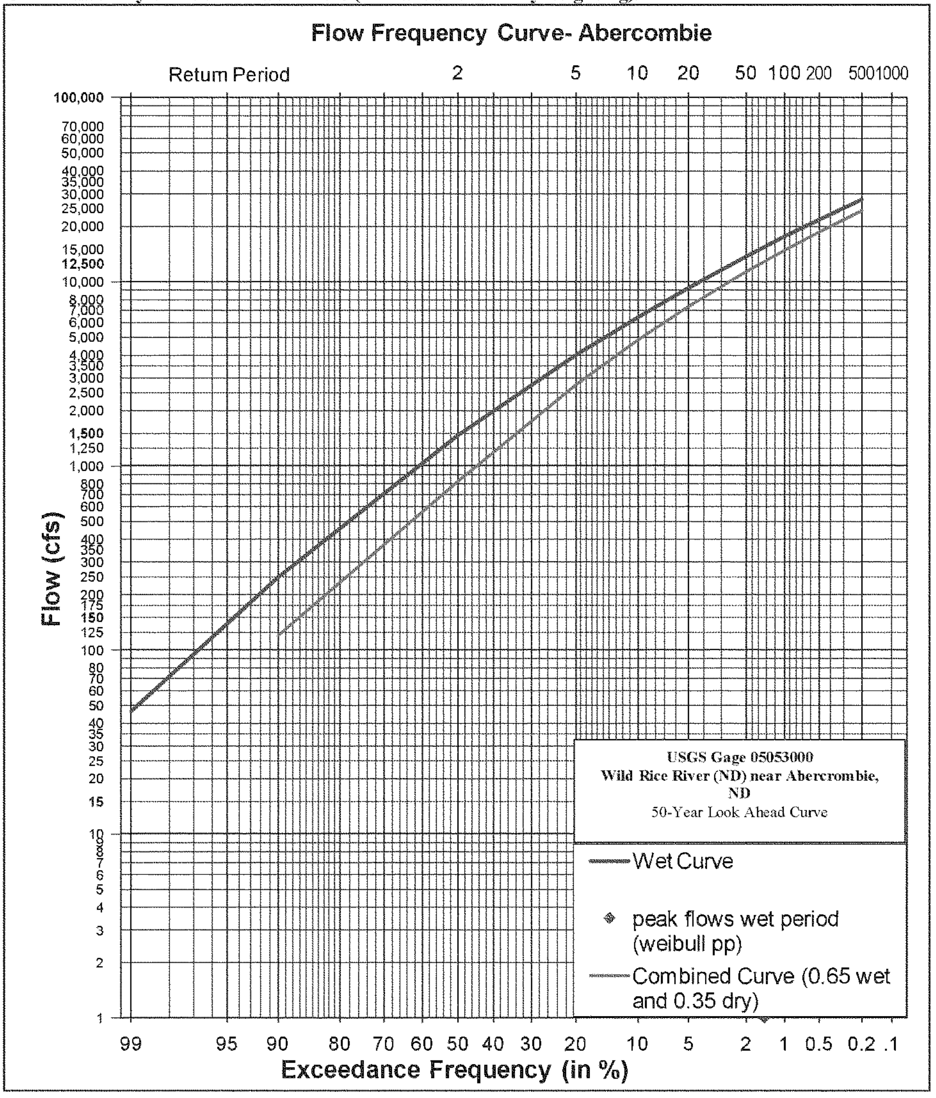
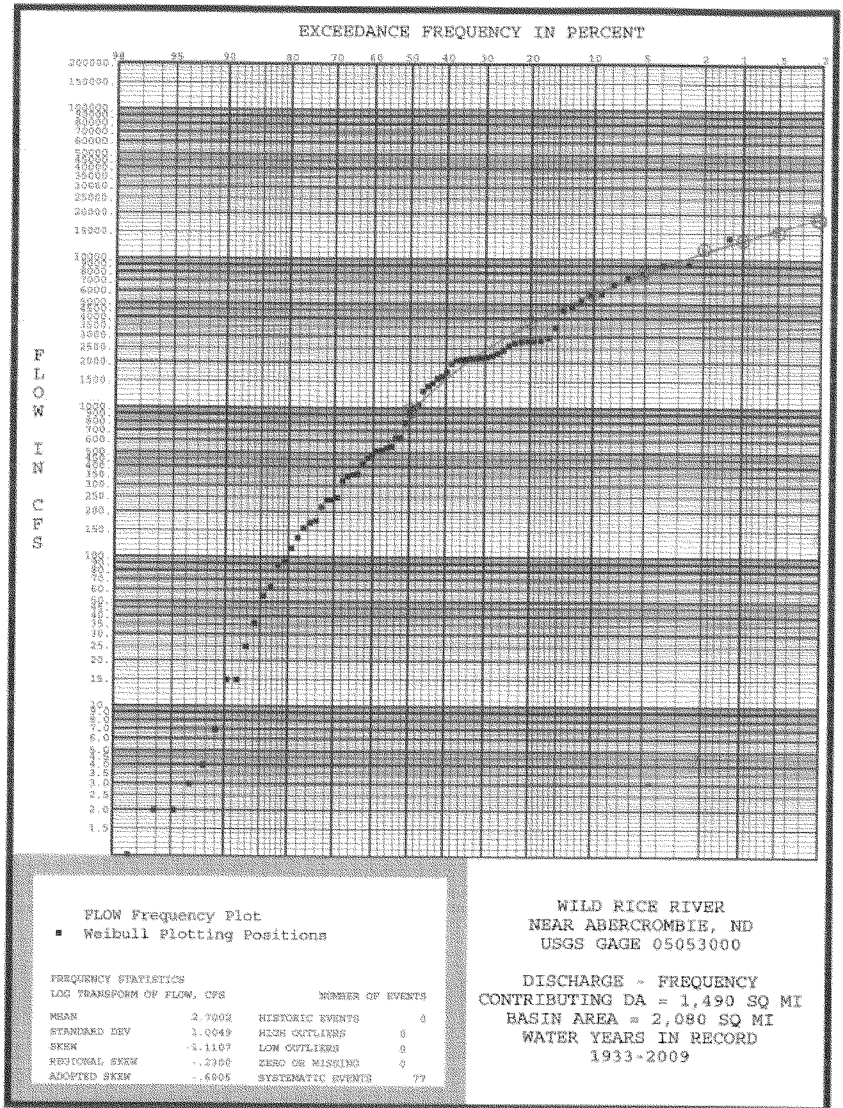


Figure 24. Wild Rice River near Abercrombie, ND Coincidental Peak Flow Frequency Curve- Full Period.



Pencil Line = Graphical Flow Frequency Curve

Figure 25. Coincidental Flow-Frequency Curve for the WET (1942-2009 portion of the POR at the Mouth of the Wild Rice River (ND) - Based on the Coincidental Flow Record at USGS Gage 05053000 Wild Rice River (ND) near Abercrombie, ND

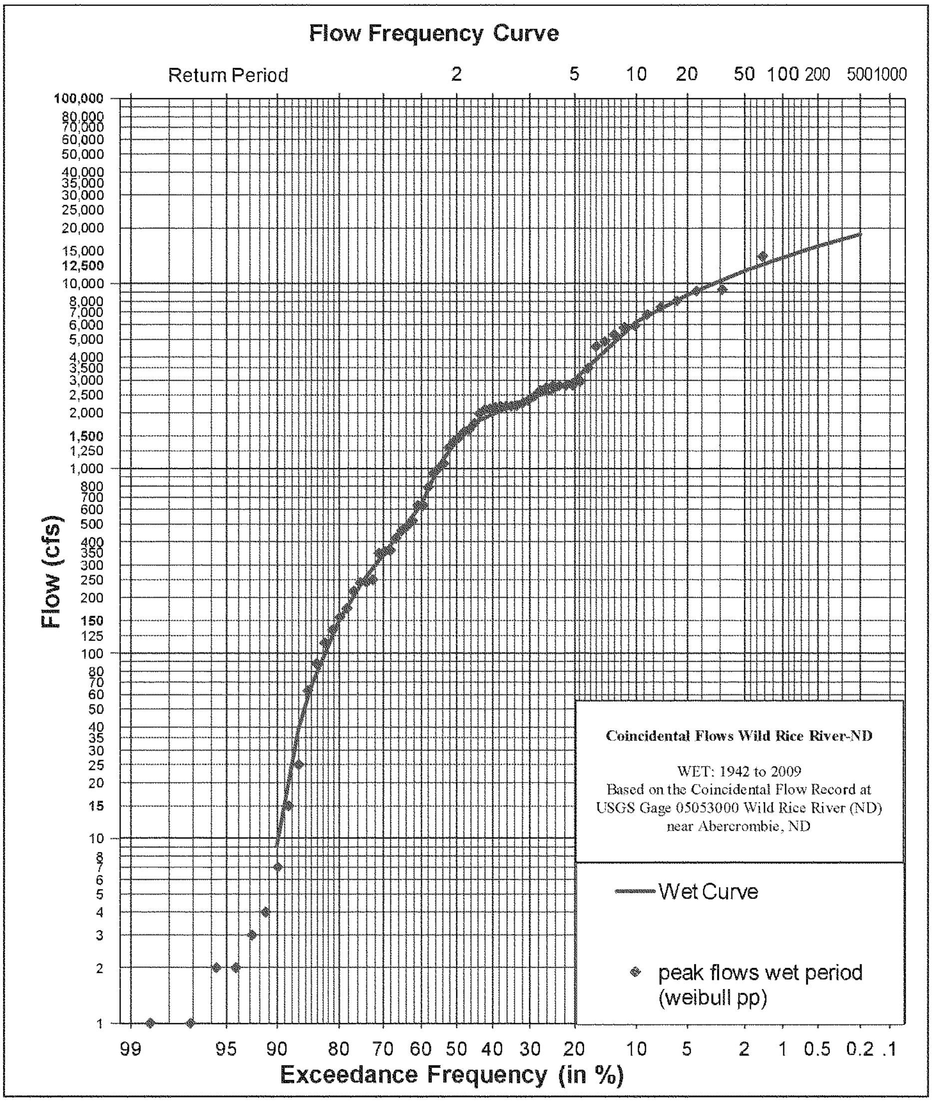


Figure 26. Mouth of the Wild Rice River (ND) near Abercrombie, ND Coincidental Flow Frequency for Wet and 25-year Look Ahead Curves (0.8 wet and 0.35 dry weighting).

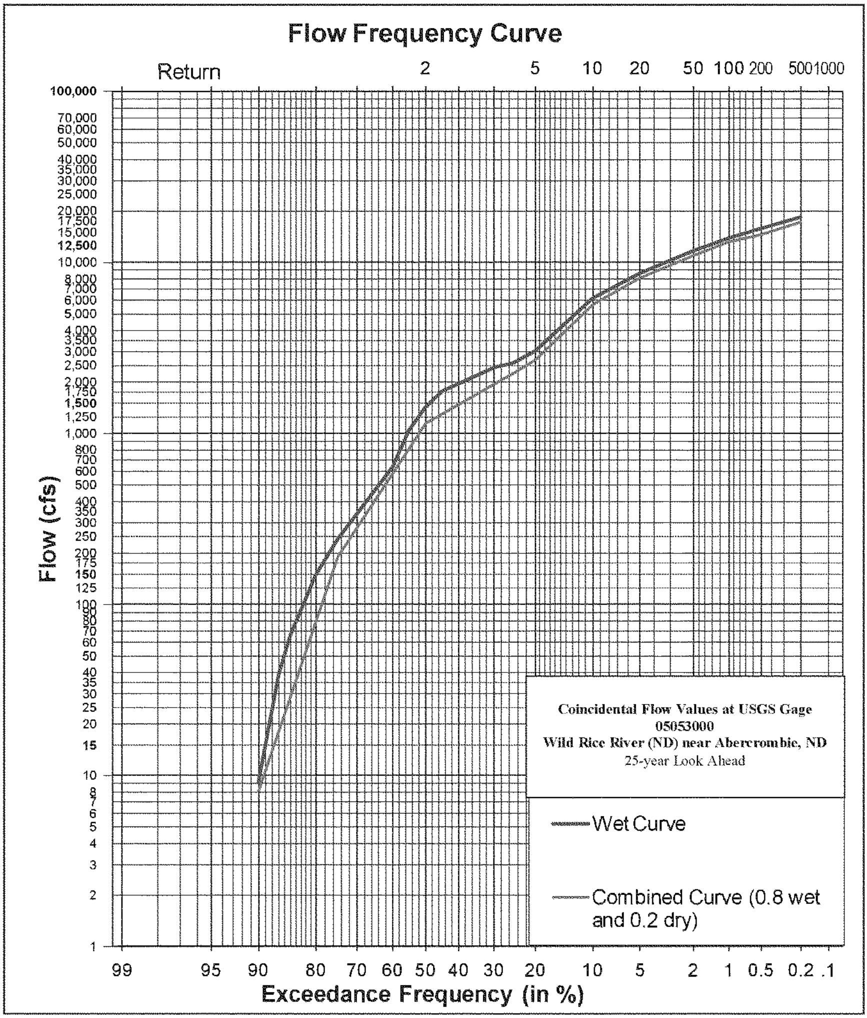


Figure 27. Mouth of the Wild Rice River near Abercrombie, ND Coincidental flow frequency for Wet and 50 year Look Ahead curves (0.65 wet and 0.35 dry).

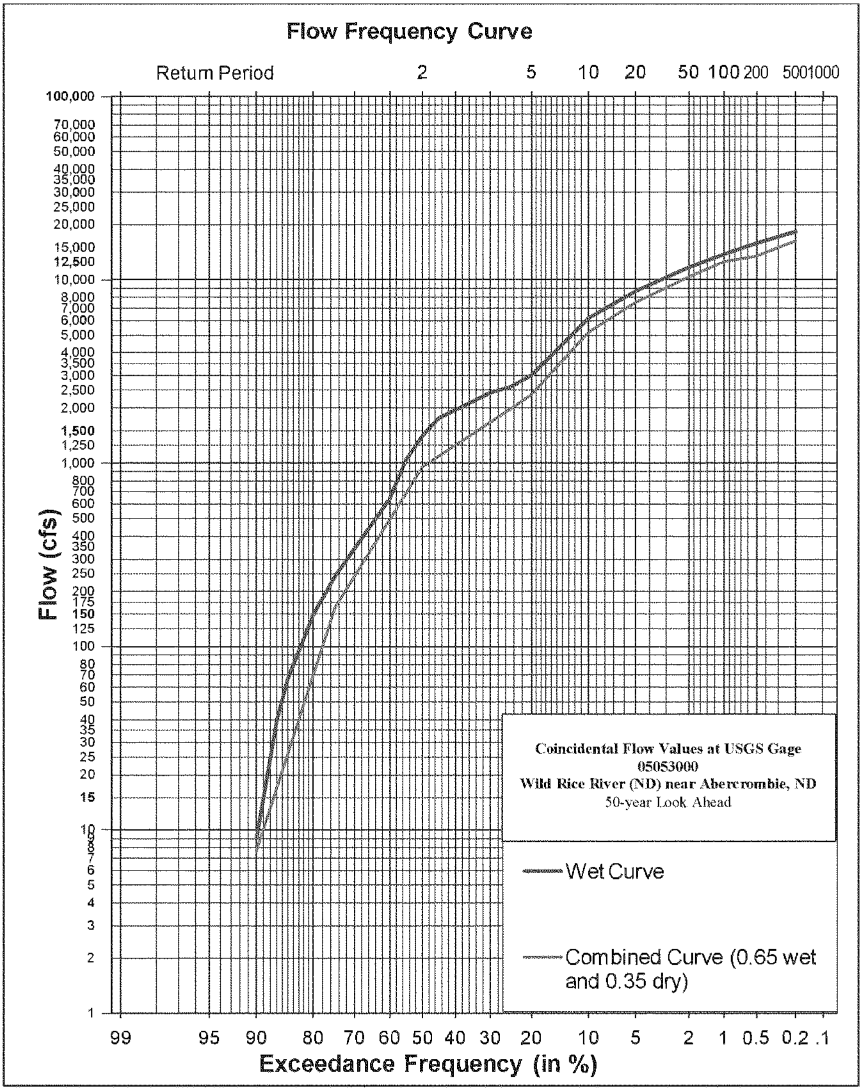


Figure 28. Schematic of the Buffalo River (2011 Google Image- USDA Farm Service Agency)

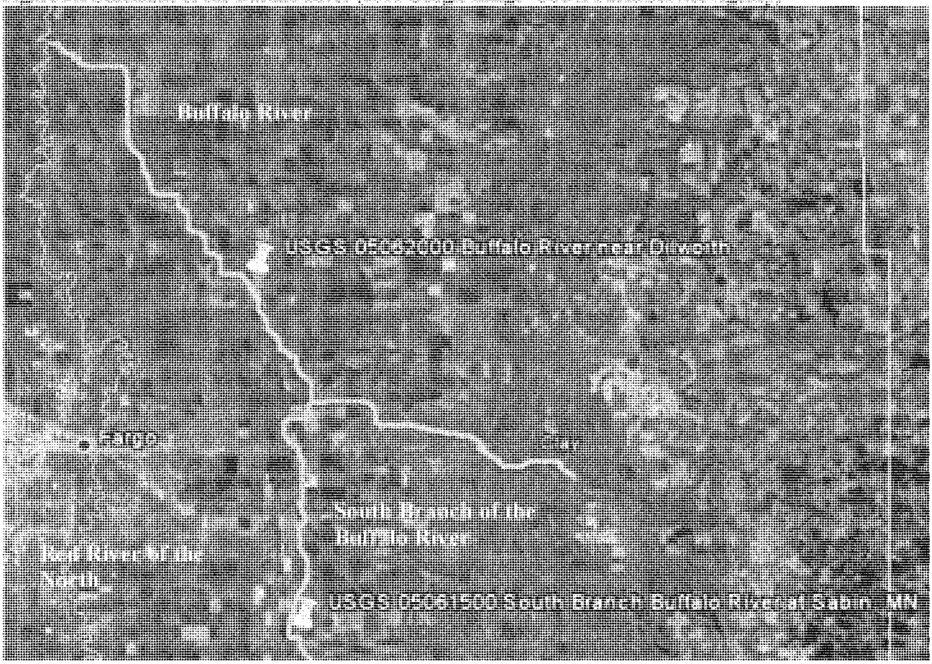
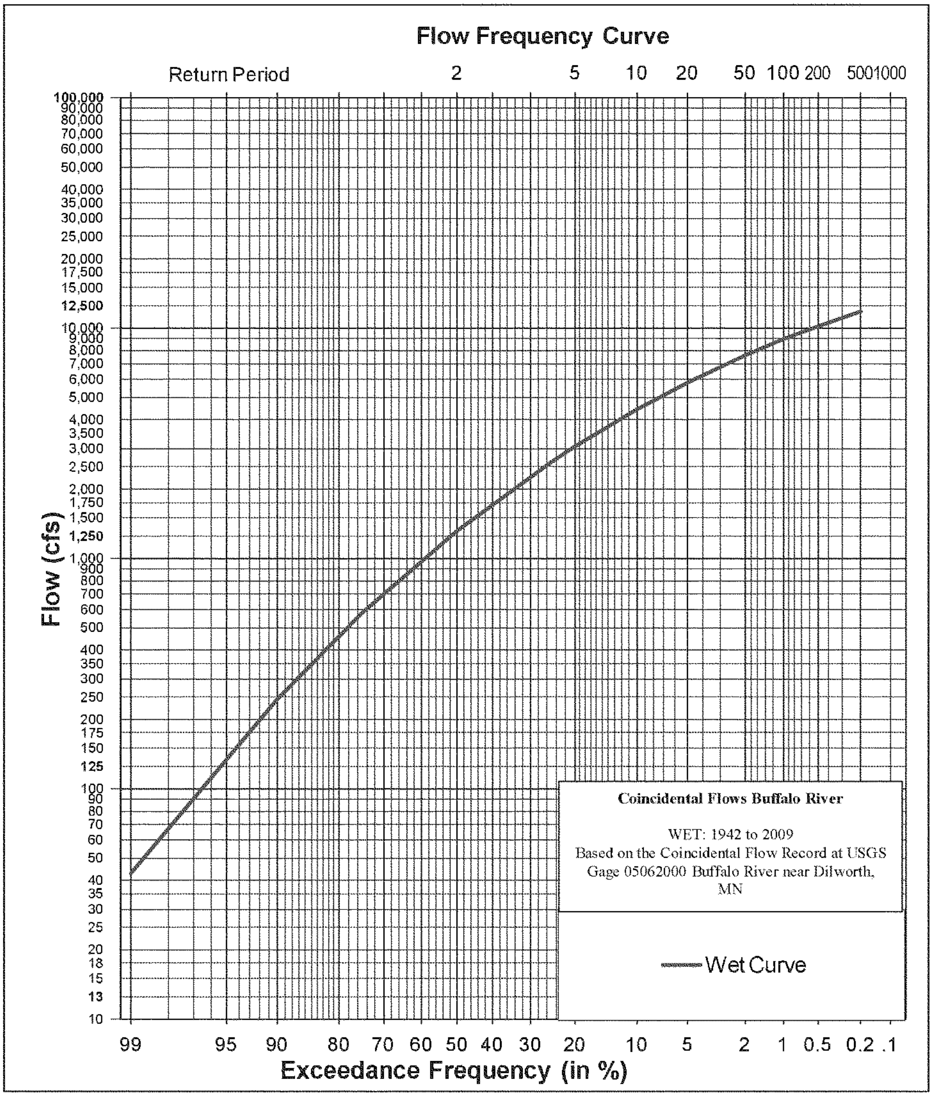


Figure 29. Coincidental Flow-Frequency Curve for the WET (1942-2009) portion of the POR at the Mouth of the Buffalo River - Based on the Coincidental Flow Record at USGS Gage 05062000 Buffalo River Near Dilworth, MN



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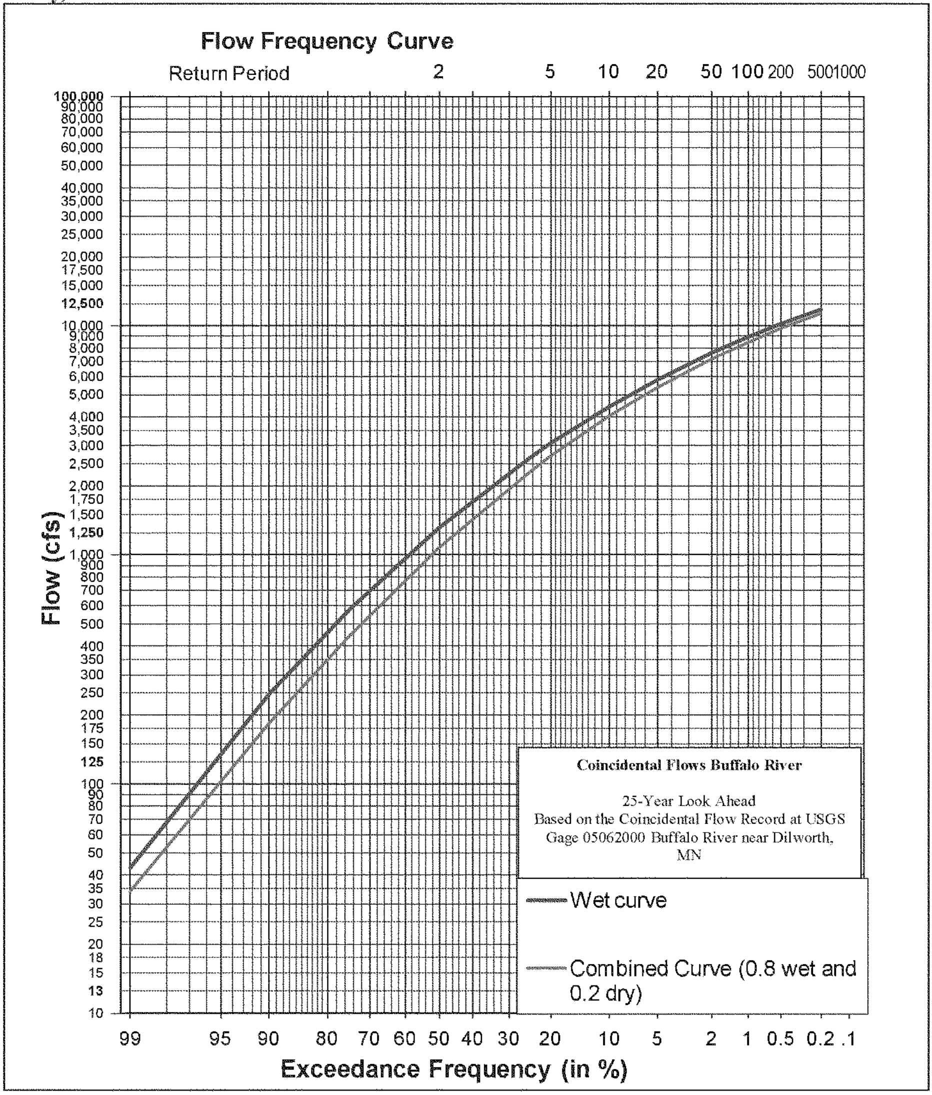


Figure 31. Buffalo River Coincident Flow Frequency Curve for Wet and 50-year Look Ahead (0.65 wet and 0.35 dry) Curves.

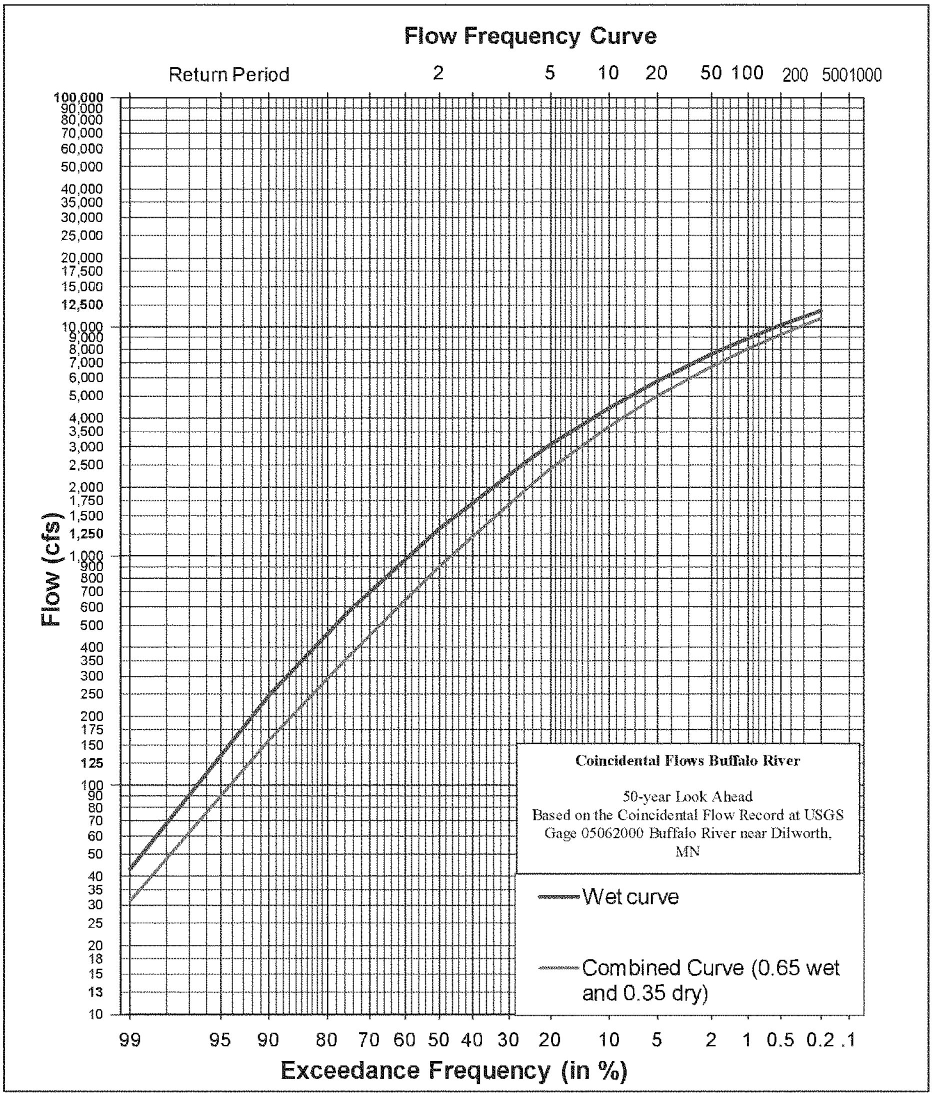


Figure 32. Coincidental Flow-Frequency Curve for the WET portion of the POR (1944-2009) at the Mouth of the Wild Rice River (MN) - Based on the Coincidental Flow Record at USGS Gage 05064000 Wild Rice River (MN) at Hendrum, MN

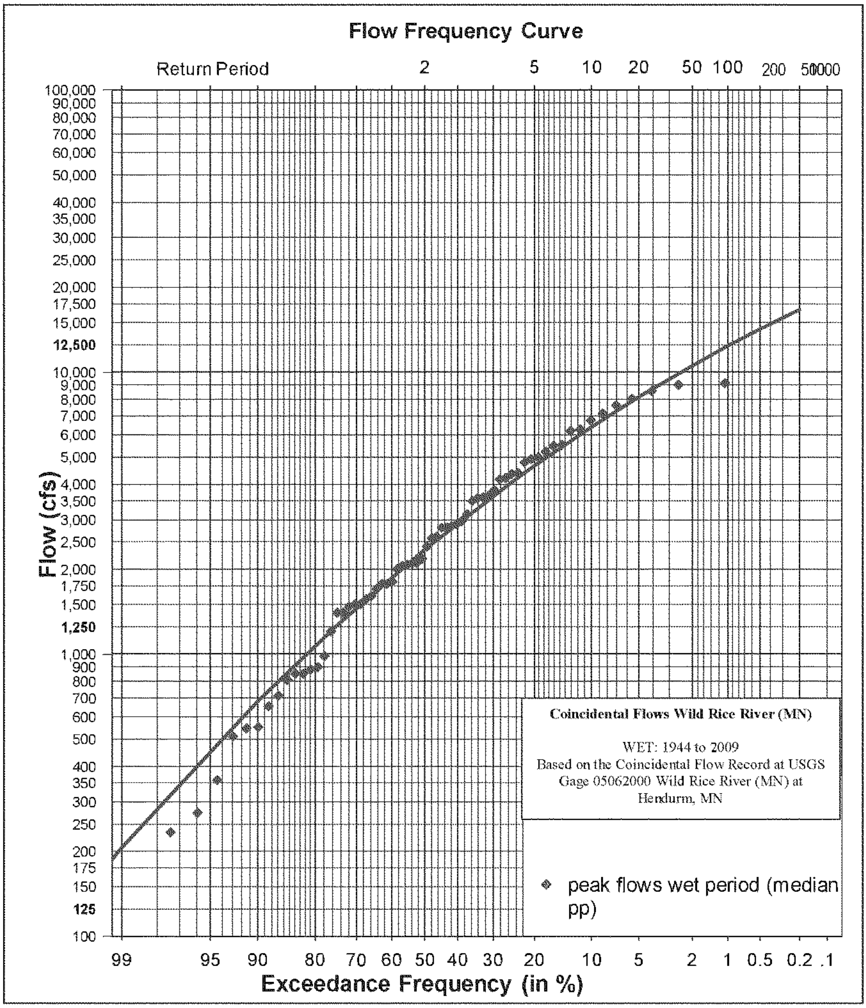


Figure 33. Wild Rice River, MN coincident Flow Frequency for Wet and 25-year Look Ahead (0.8 wet and 0.2 dry) curves.

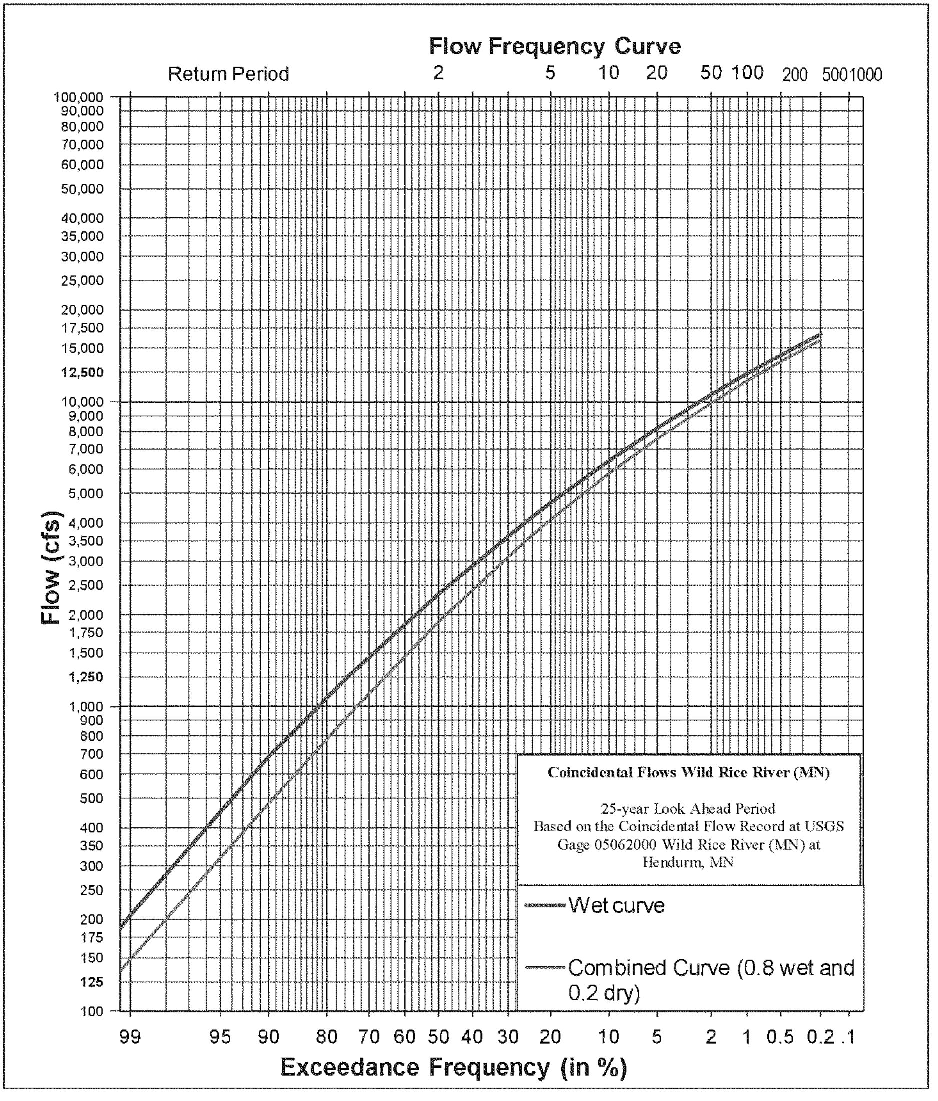
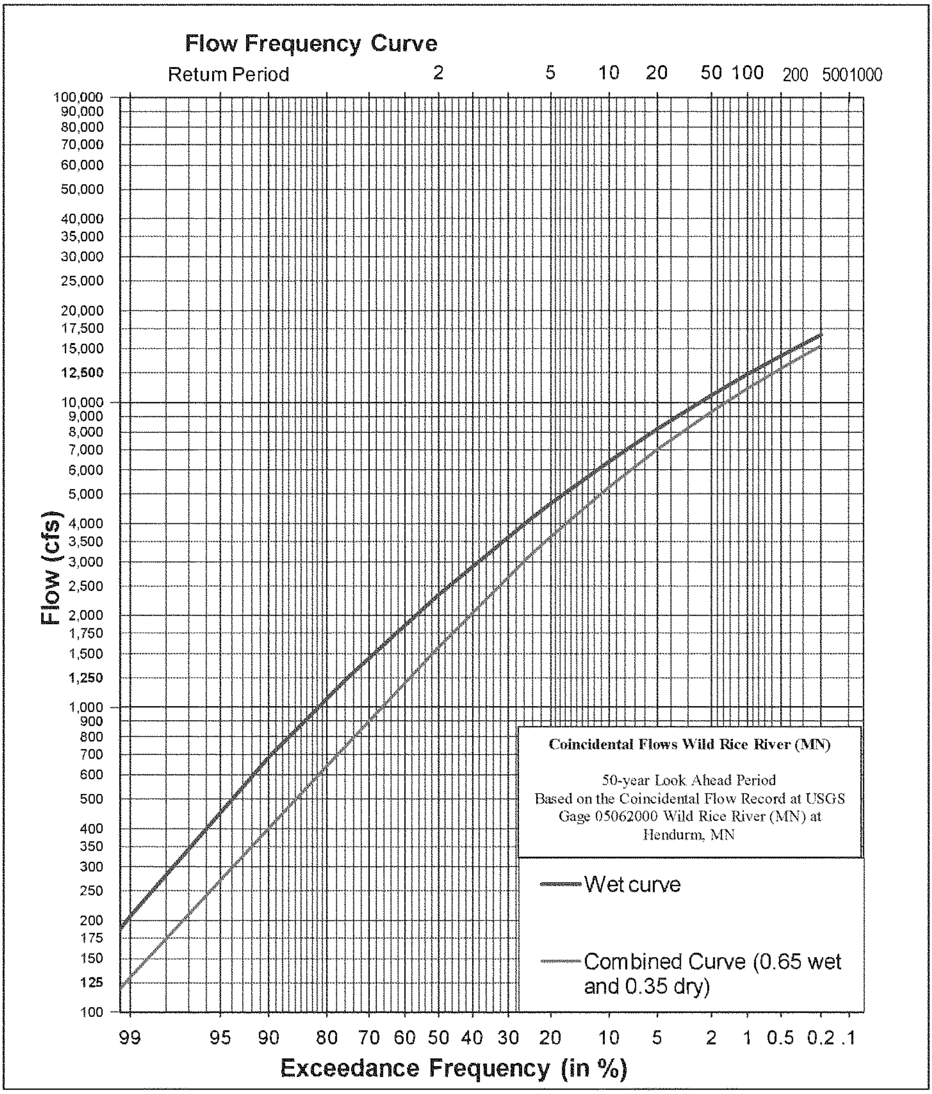


Figure 34. Wild Rice River, MN coincident Flow Frequency for Wet and 50-year Look Ahead Period (0.65 wet and 0.35 dry) curves.



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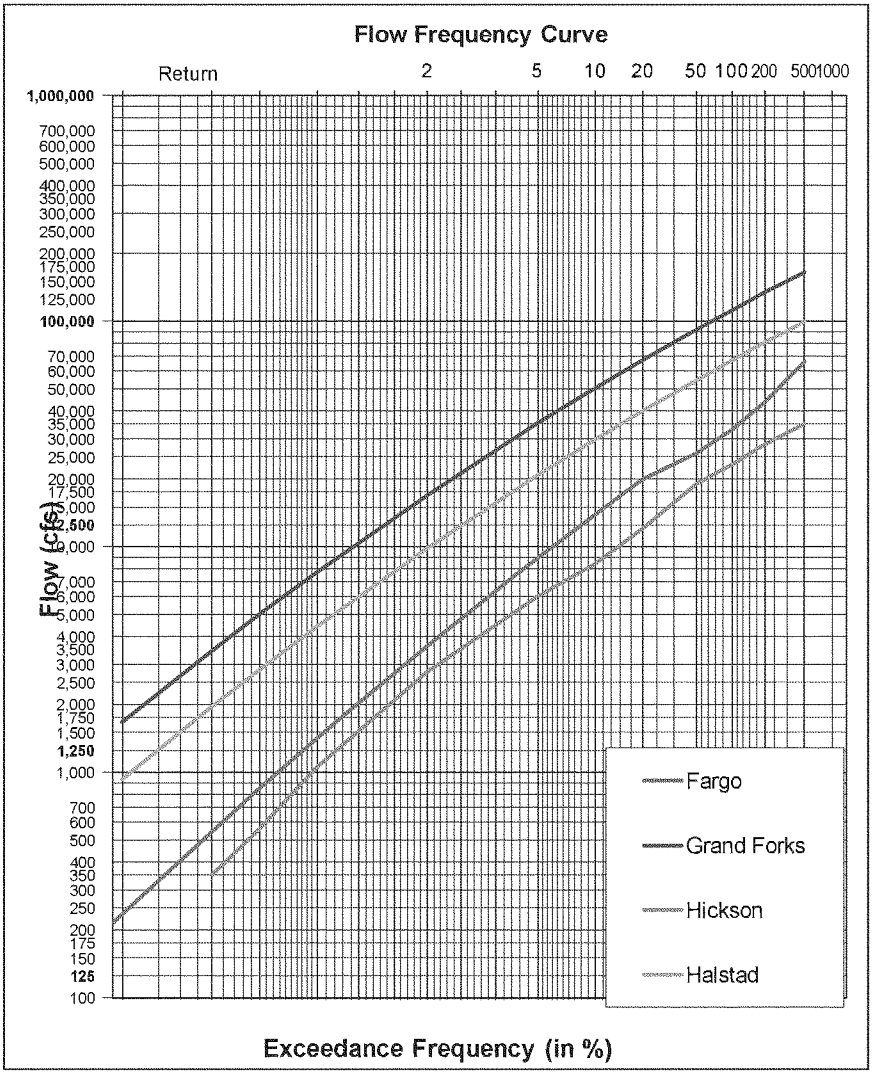


Figure 36. Red River of the North Discharge Frequency Curves- WET (1942-2009)

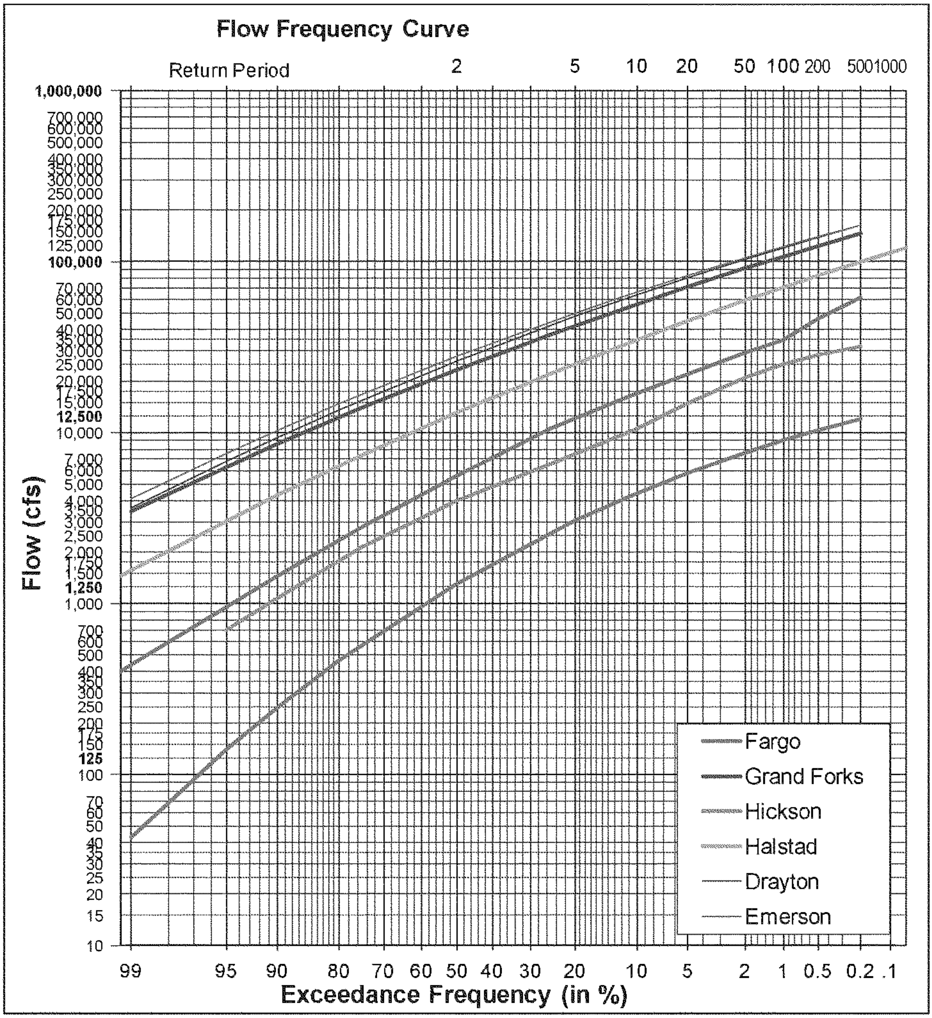


Figure 37. Red River of the North Discharge Frequency Curves- 25- yr Look Ahead Combined Curves

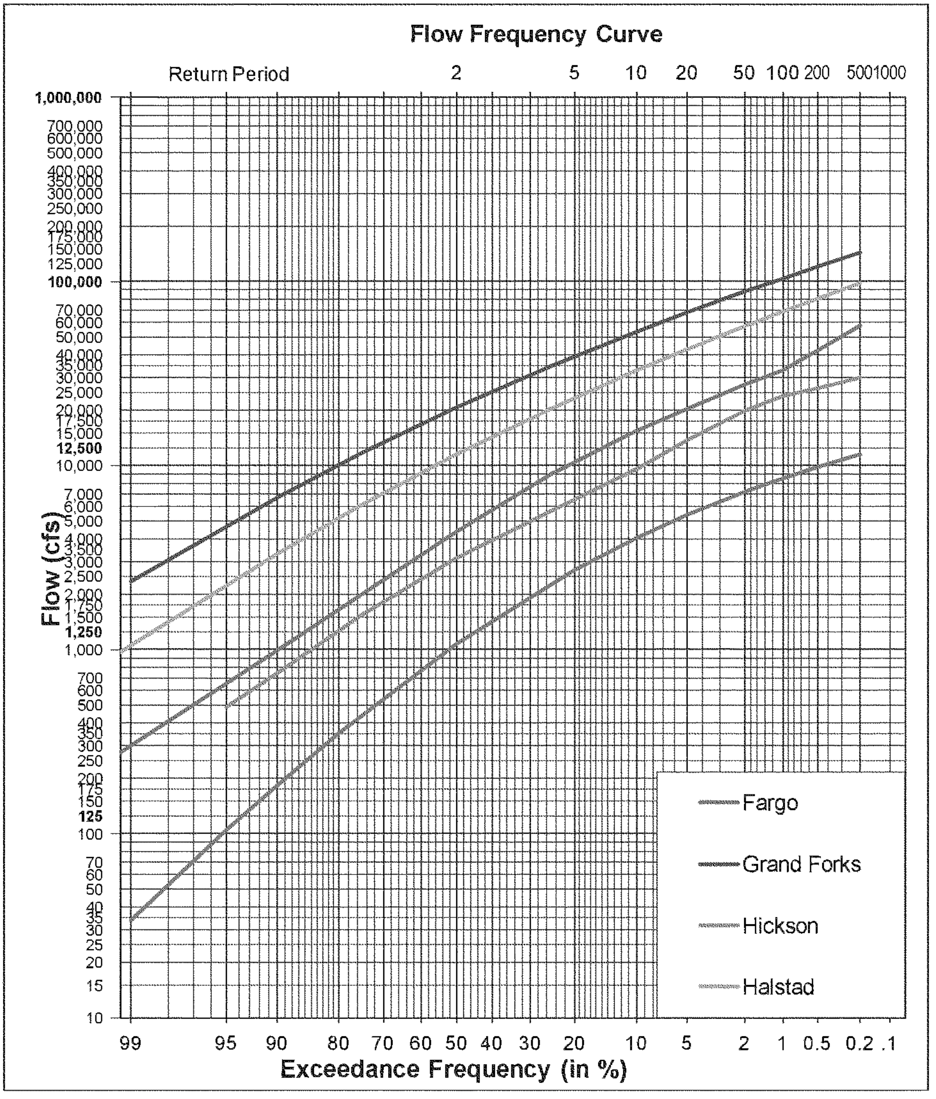


Figure 38. Red River of the North Discharge Frequency Curves- 50- yr Look Ahead Combined Curves

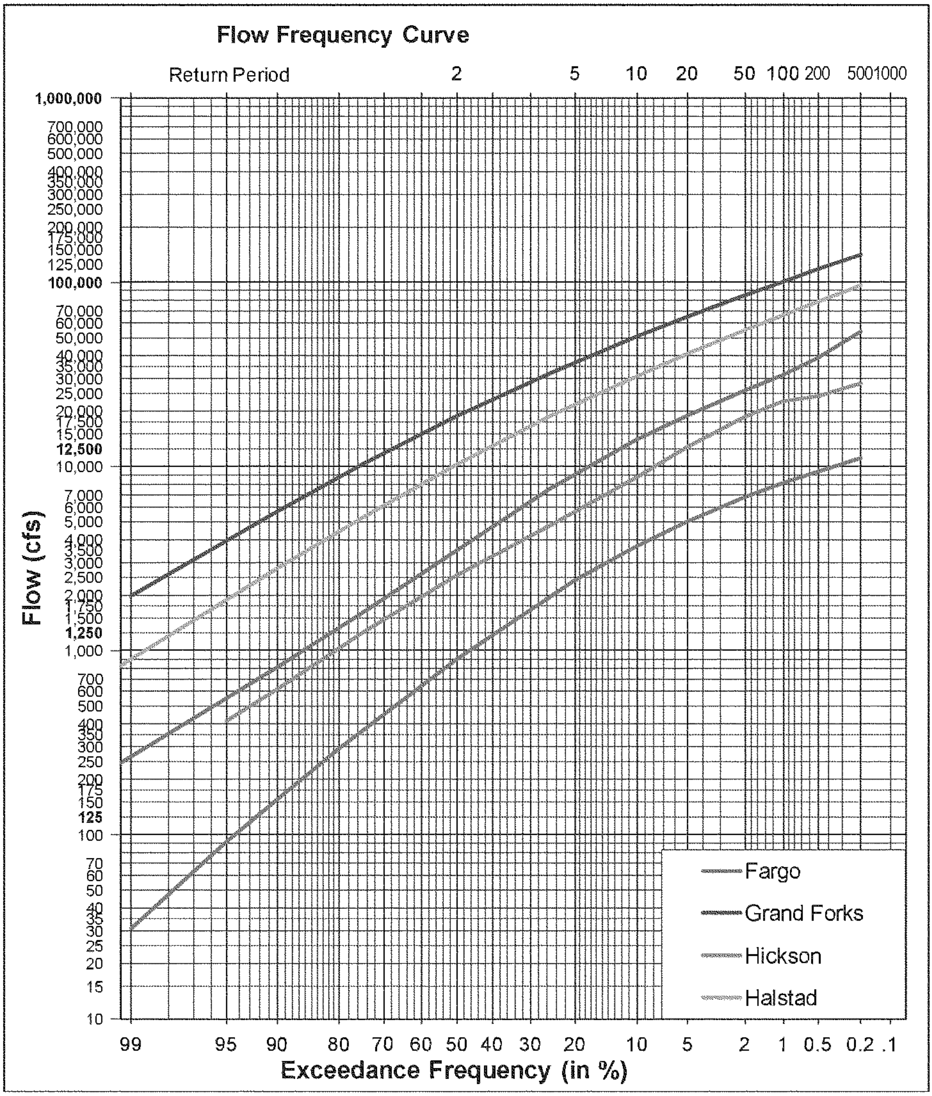


Figure 39 Volume Duration Frequency Analytical Plot for Red River at Fargo, ND Flood Volume Frequency

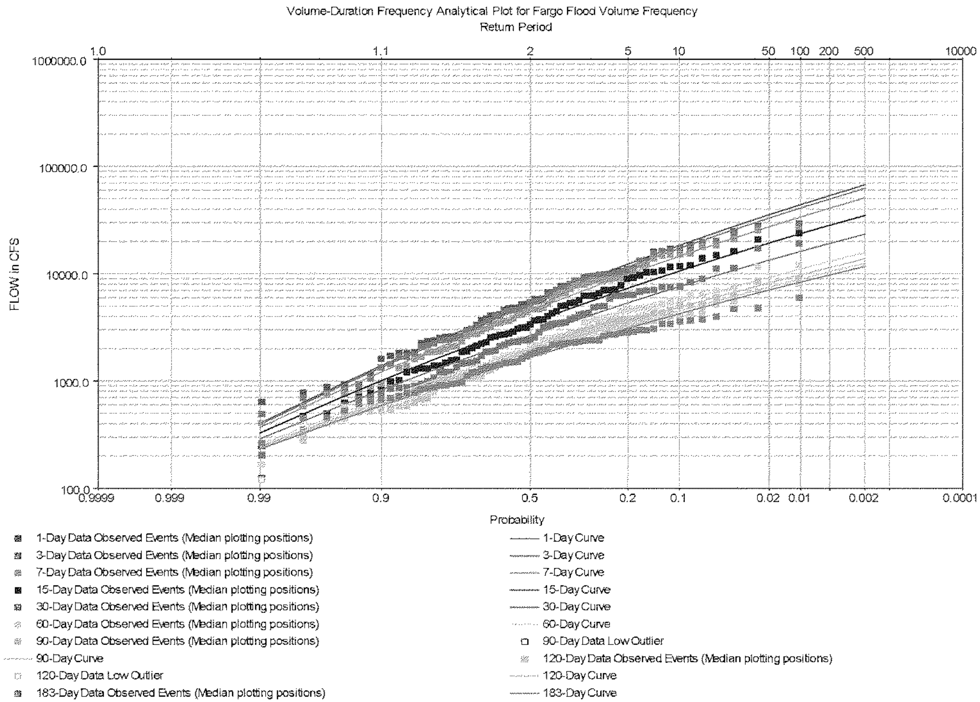


Figure 40- Volume Duration Frequency Analytical Plot for Wild Rice River at Abercrombie, ND Flood Volume Frequency

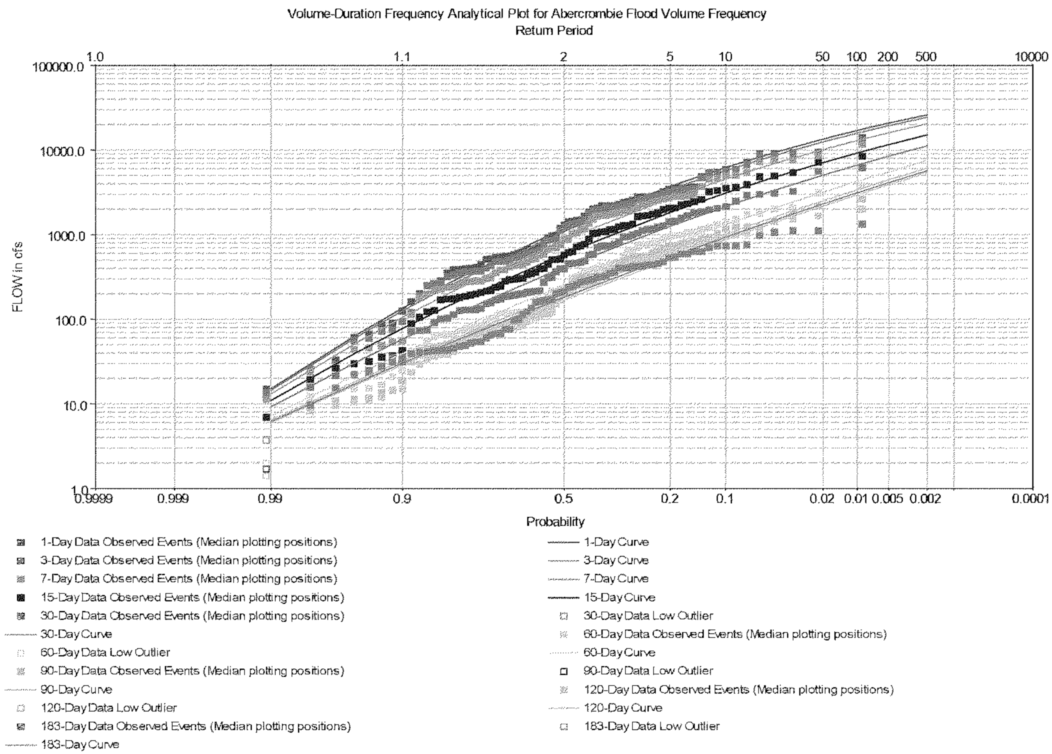


Figure 41- Volume Duration Frequency Analytical Plot for Buffalo River at Dilworth, MN Flood Volume Frequency

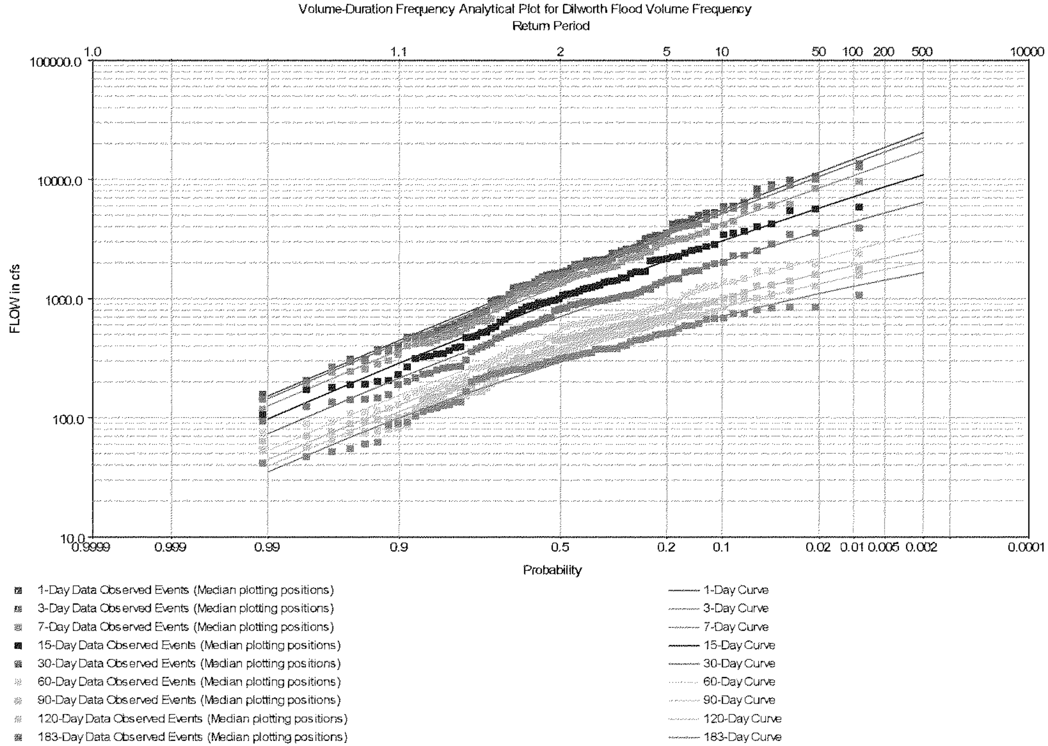


Figure 42- Volume Duration Frequency Analytical Plot for Red River at Halstad, MN Flood Volume Frequency

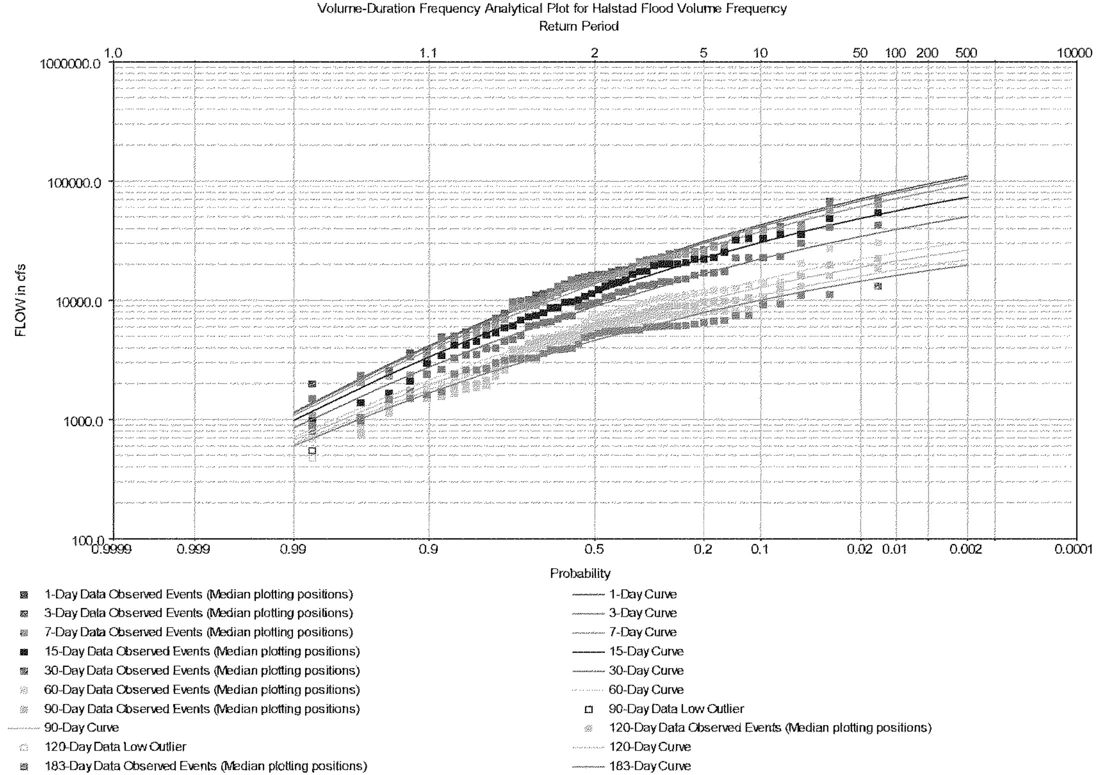
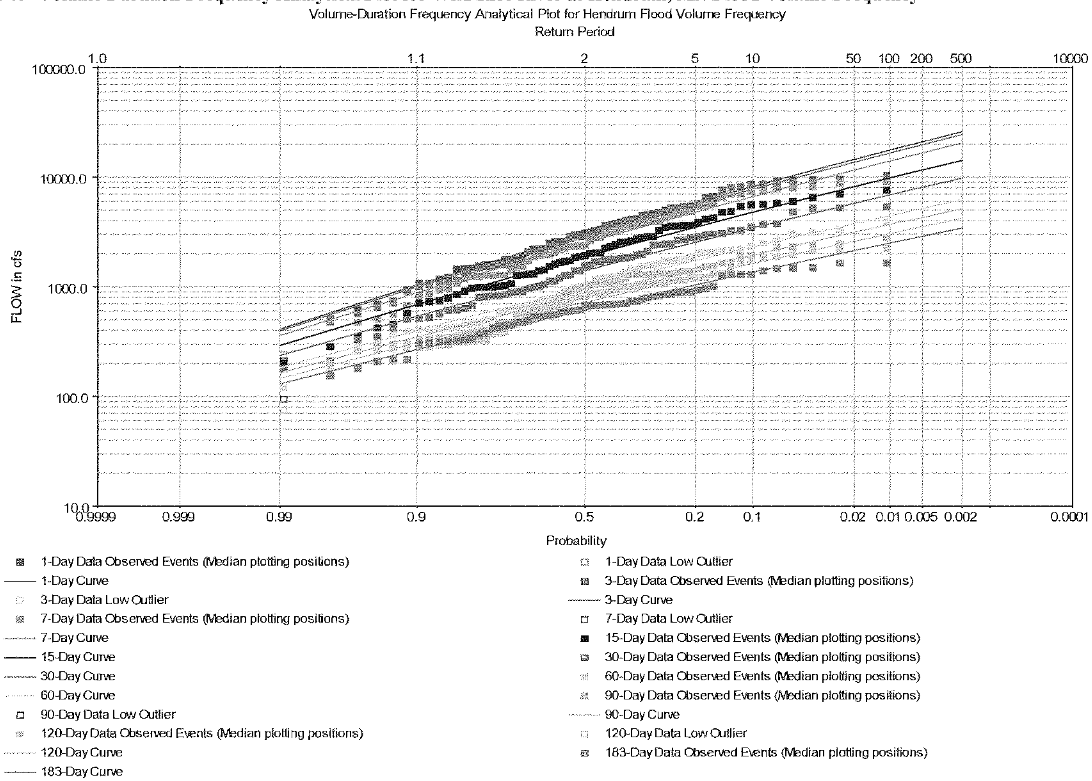


Figure 43- Volume Duration Frequency Analytical Plot for Wild Rice River at Hendrum, MN Flood Volume Frequency



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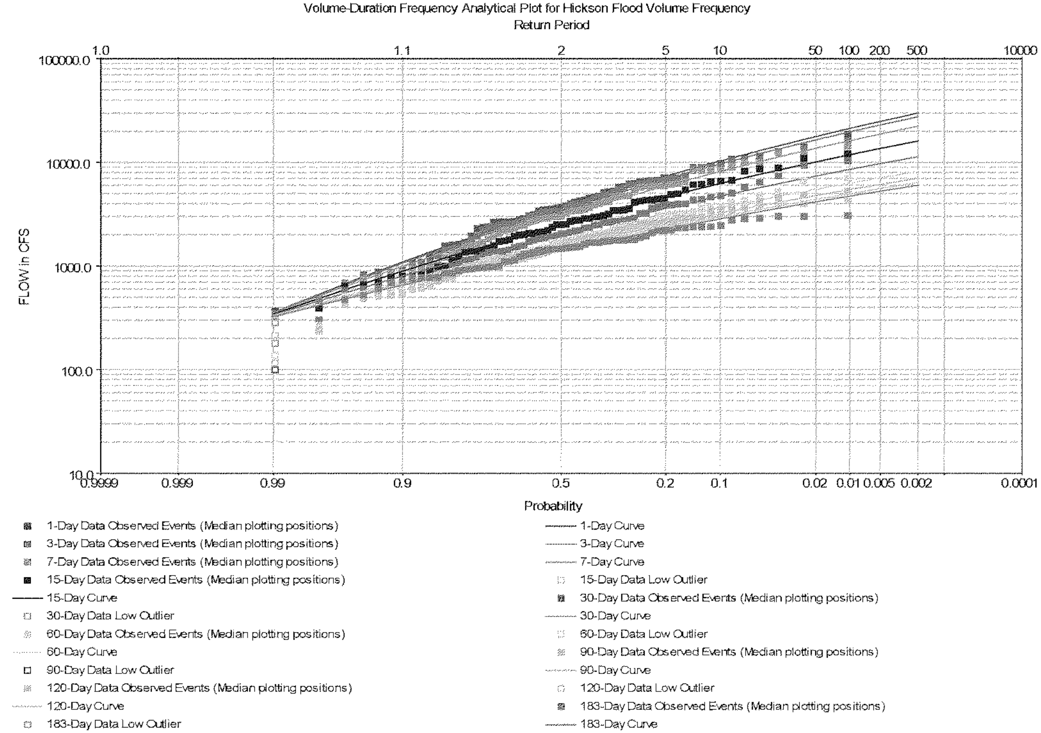
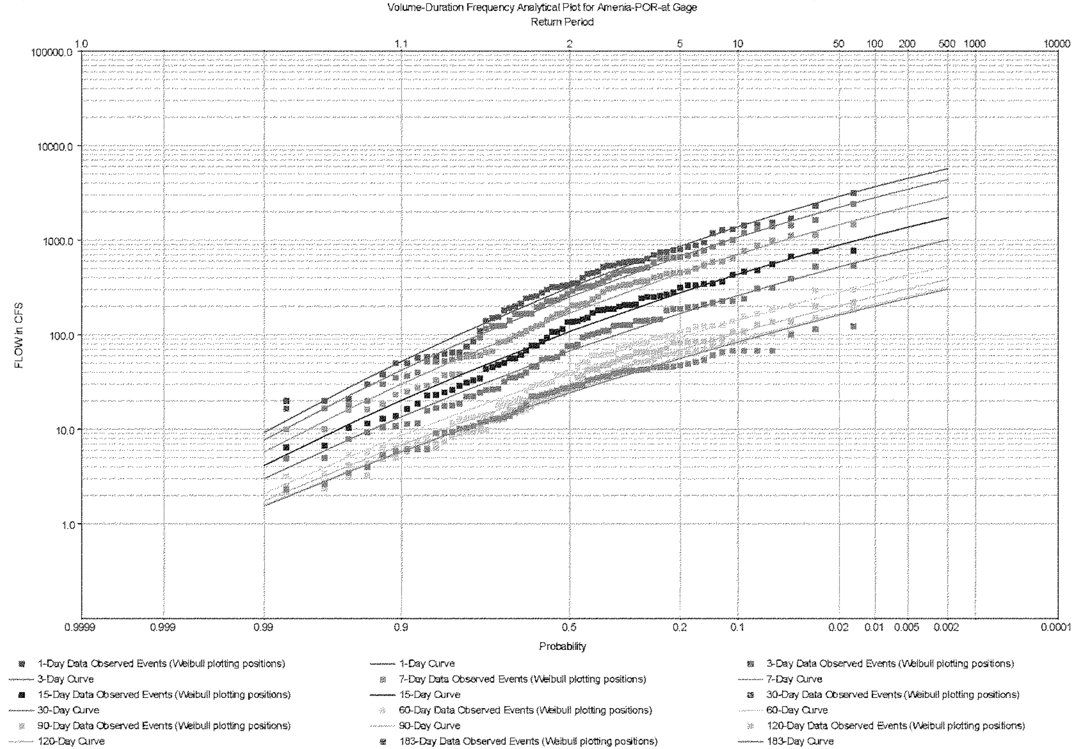


Figure 45 Volume Duration Frequency Analytical Plot for Red River at Amenia Flood Volume Frequency



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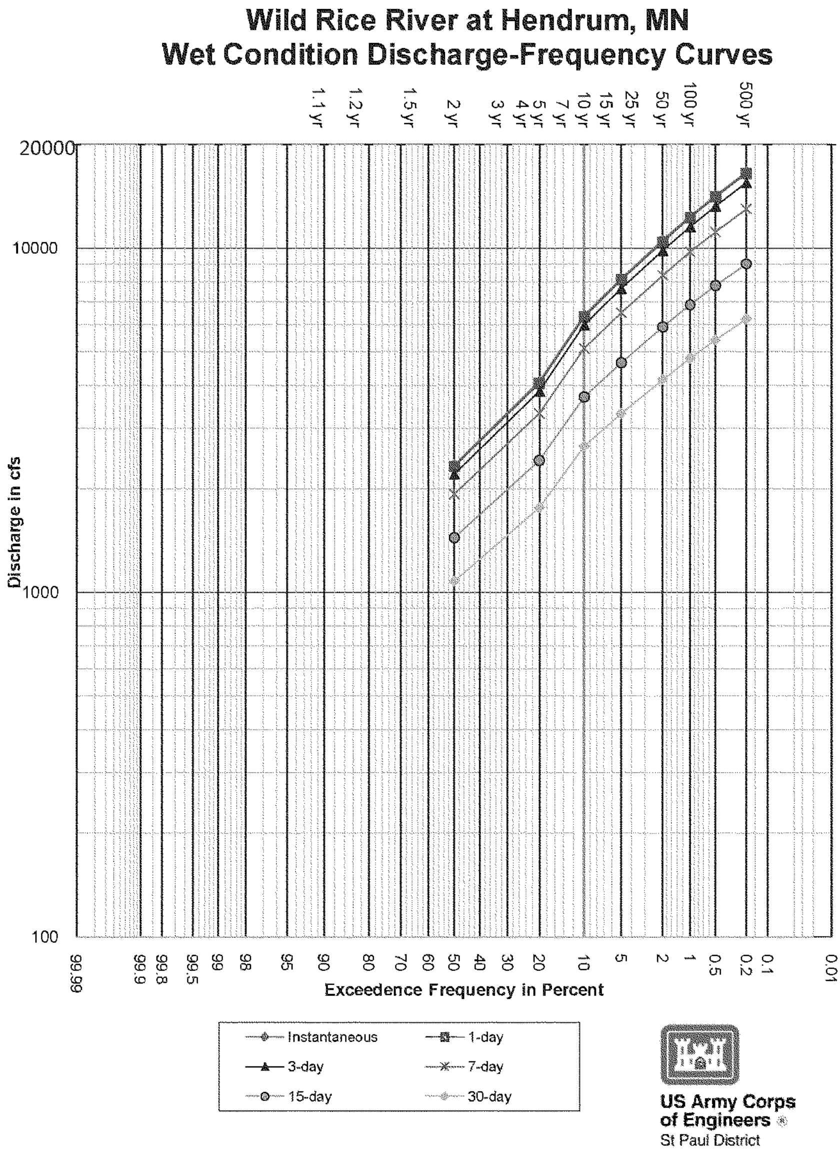


Figure 47- Wild Rice River at Hendrum, ND Flow Volume-Frequency Curves, 25 Year Look Ahead Condition (80% Wet, 20% Dry)

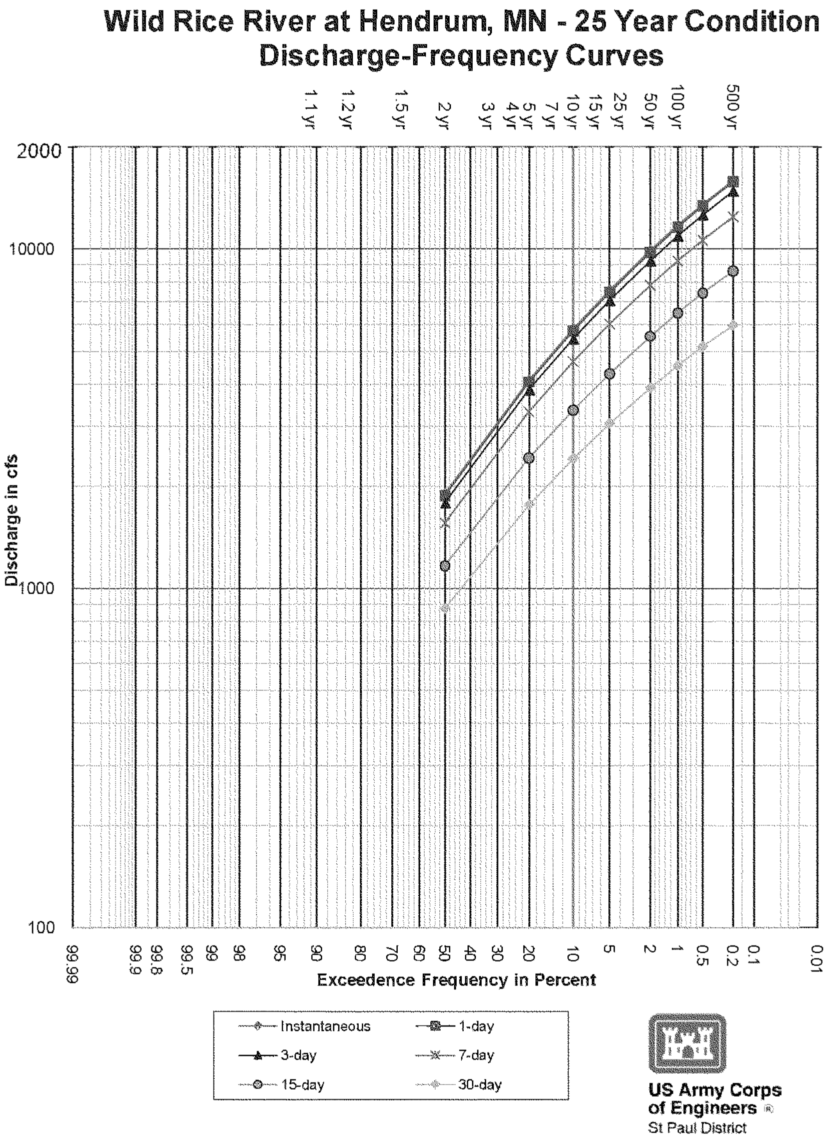


Figure 48- Wild Rice River at Hendrum, ND Flow Volume-Frequency Curves, 50 Year Look Ahead Condition (65% Wet, 35% Dry)

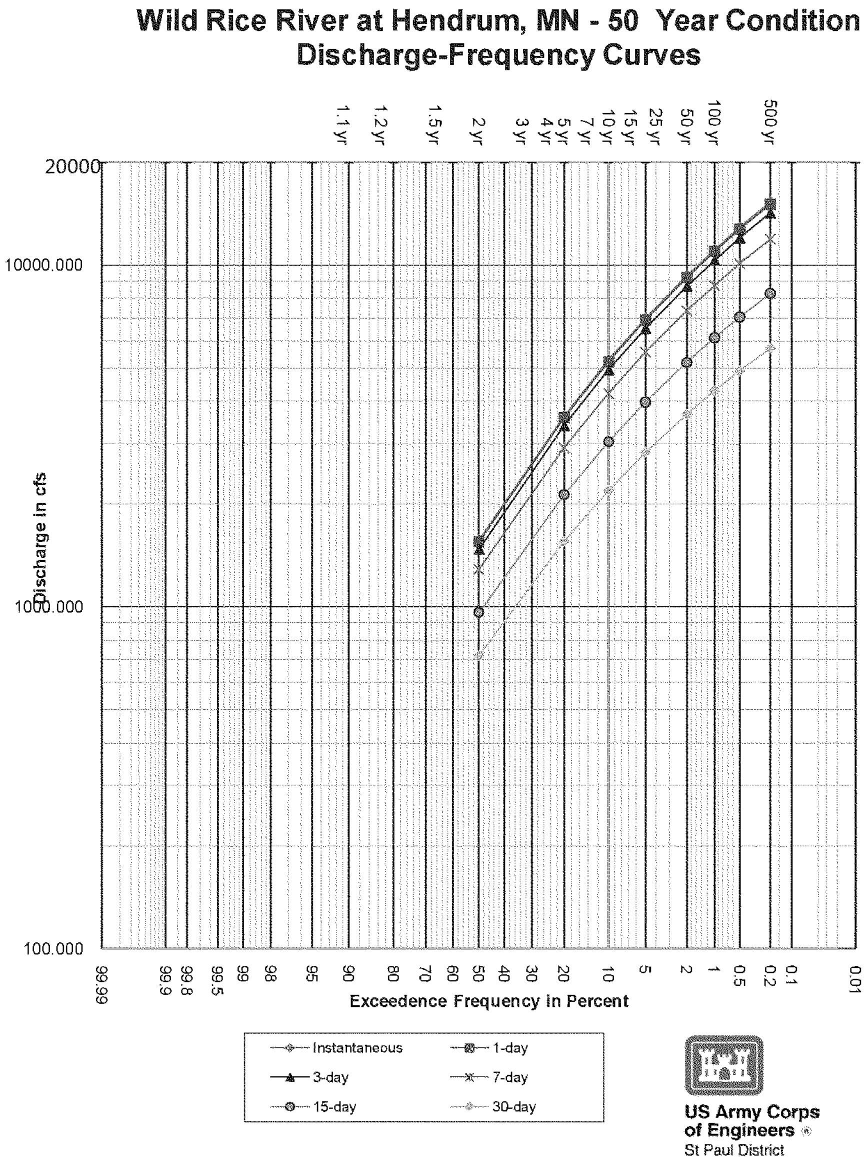


Figure 49- Balanced Hydrograph, Wild Rice River at Hendrum, MN, Wet Condition

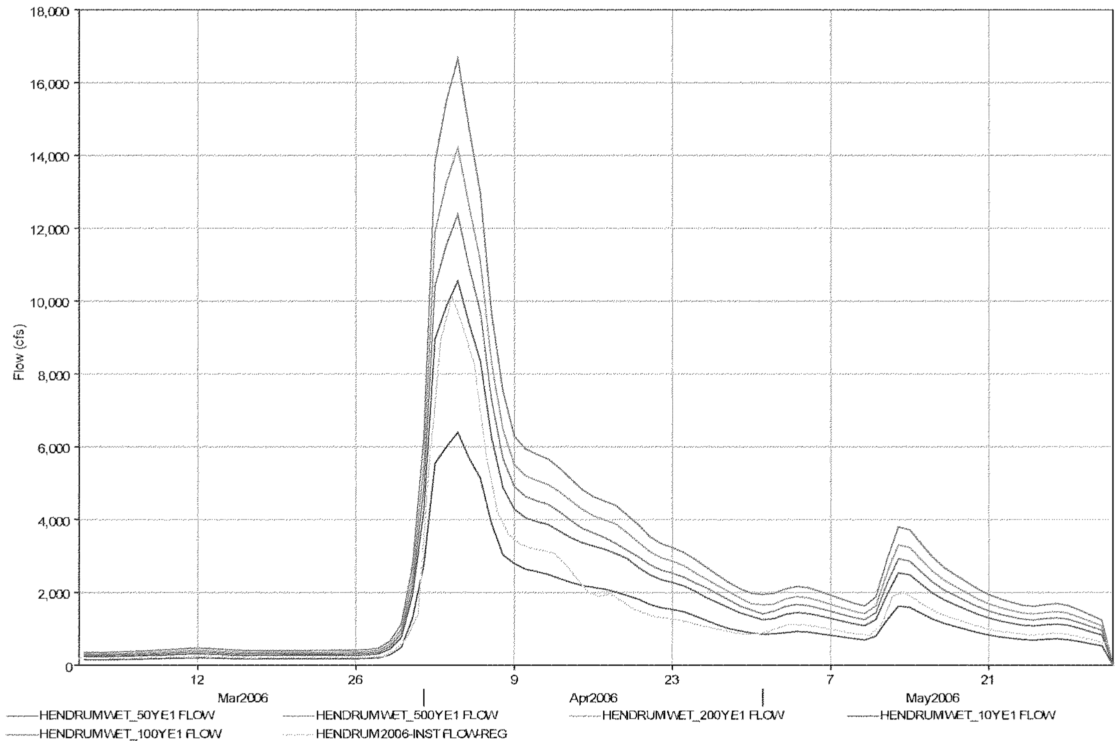


Figure 50- Balanced Hydrograph, Wild Rice River at Hendrum, MN, 25 Year Look Ahead Condition (80% Wet, 20% Dry)

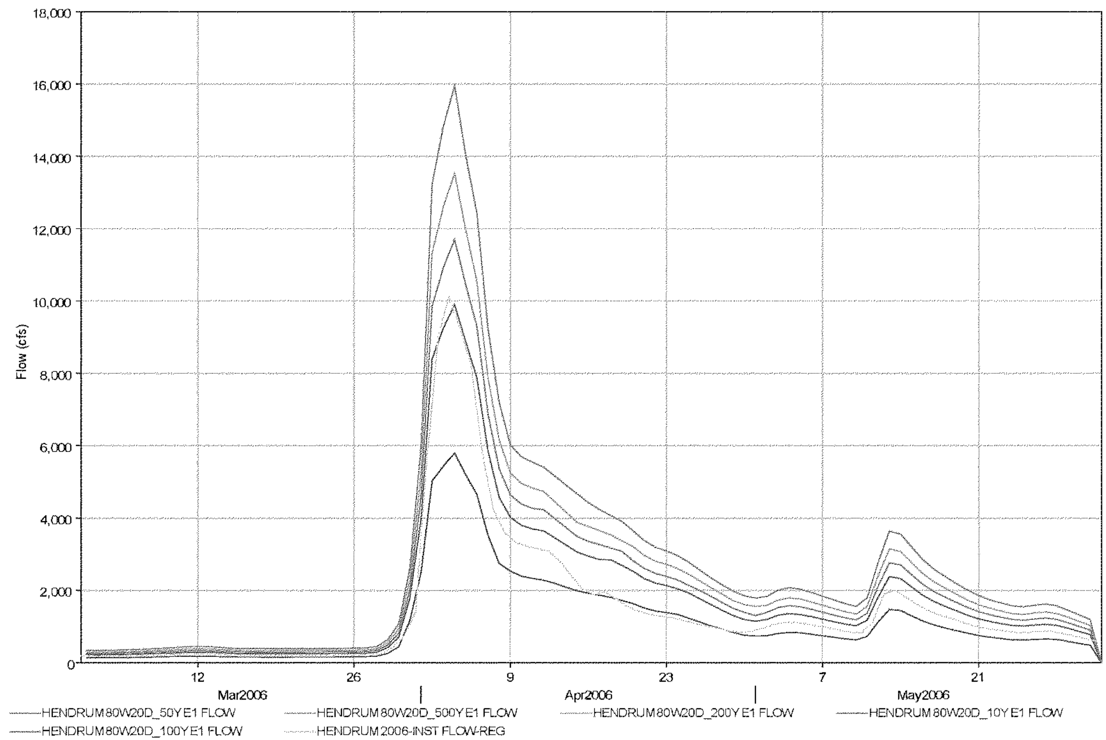
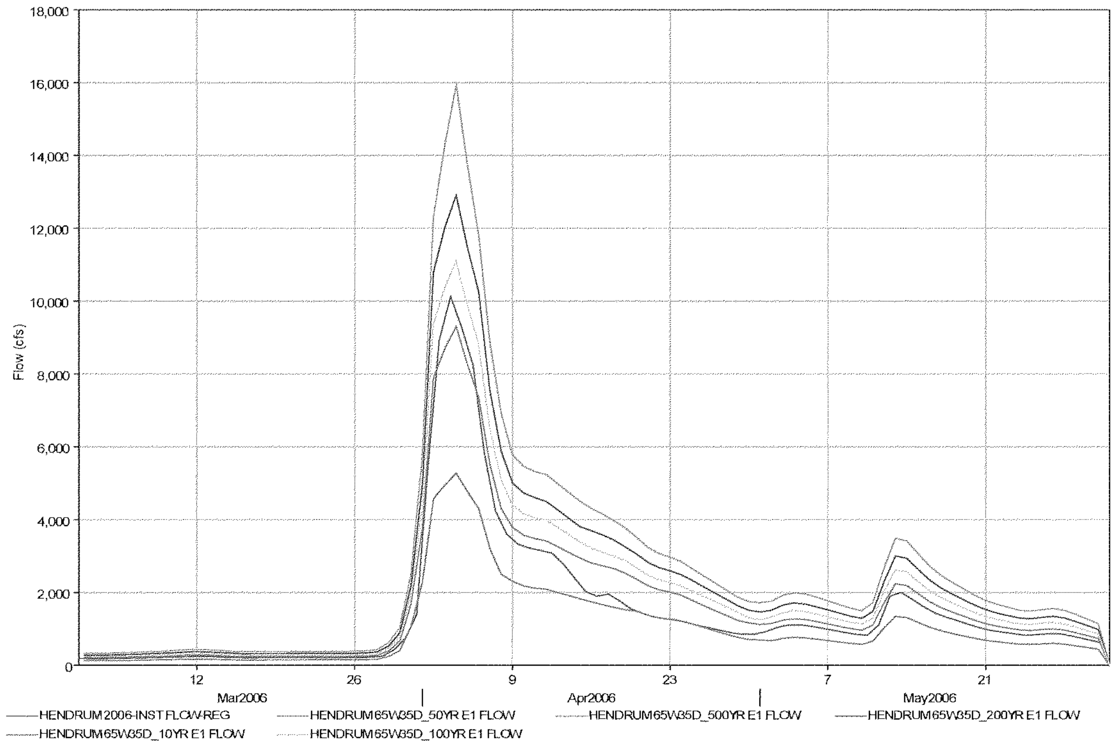


Figure 51- Balanced Hydrograph, Wild Rice River at Hendrum, MN, 50 Year Look Ahead Condition (65% Wet, 35% Dry)



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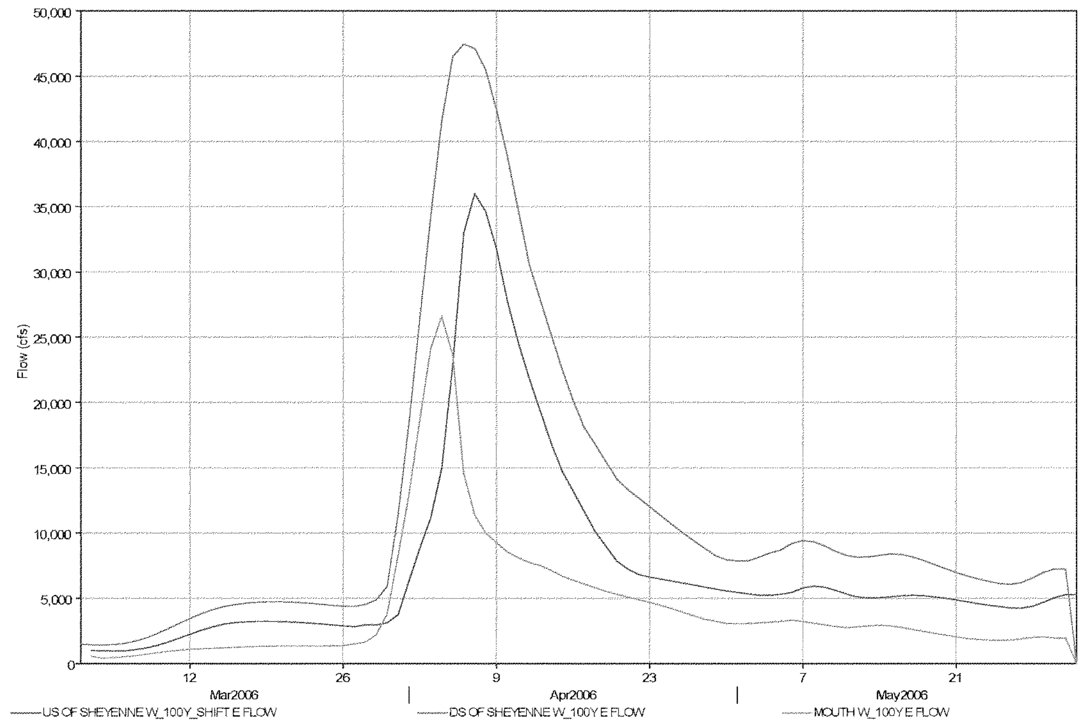


Figure 53- 100 Year Balanced Hydrographs Wet Condition, Sheyenne US and DS of Rush River and Rush River at Mouth

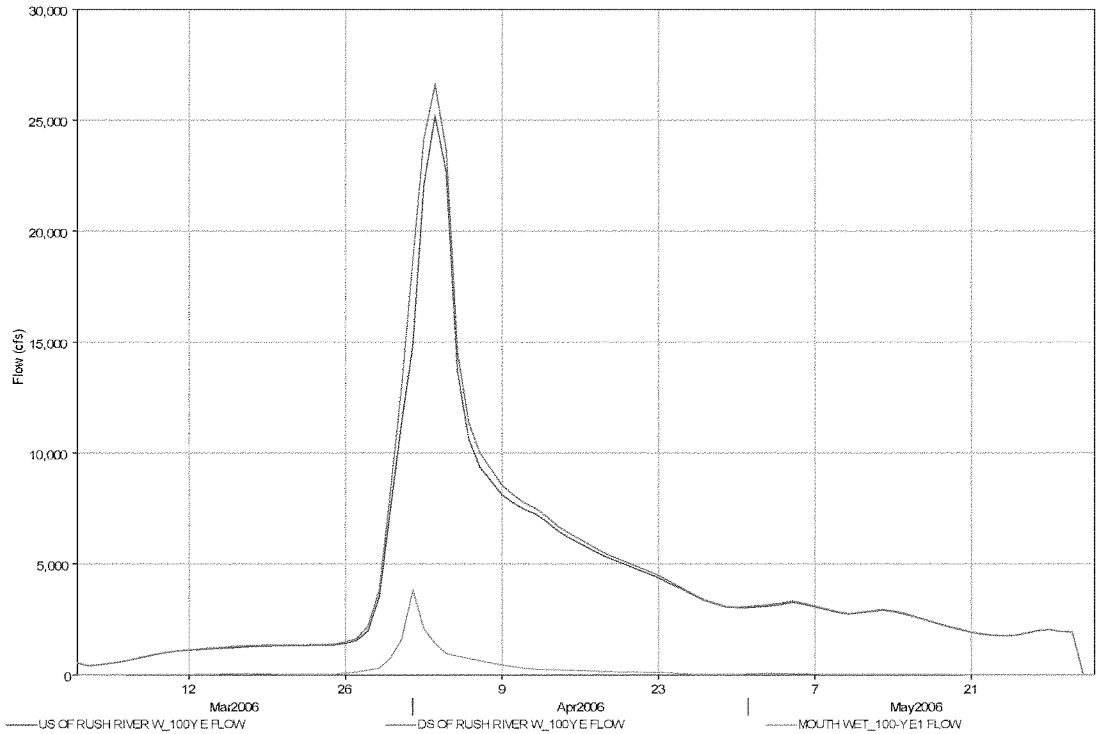


Figure 54- 100 Year Balanced Hydrographs Wet Condition, Sheyenne US and DS of Maple River and Maple River at Mouth

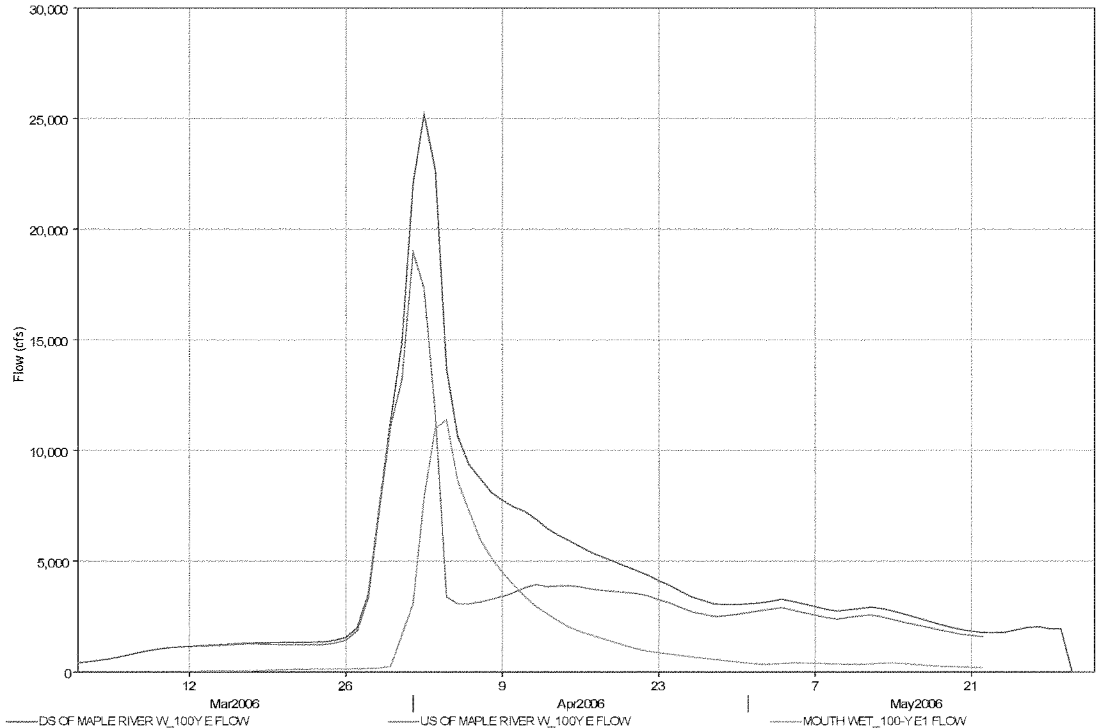


Figure 55- Diagram describing the difference in the flow-frequencies at the mouth of the Sheyenne River for the Unsteady vs. Steady RAS model

The coincident hydrograph at the mouth of the tributary (green) is obtained by subtracting the hydrograph upstream of the confluence on the main stem (blue) from the hydrograph downstream of the confluence (red) for the Steady RAS Model. The peak of the resulting coincident hydrograph may be larger than the differences in the peaks of the upstream and downstream hydrographs on the main stem due to the individual timing of the hydrographs for the Unsteady RAS model.

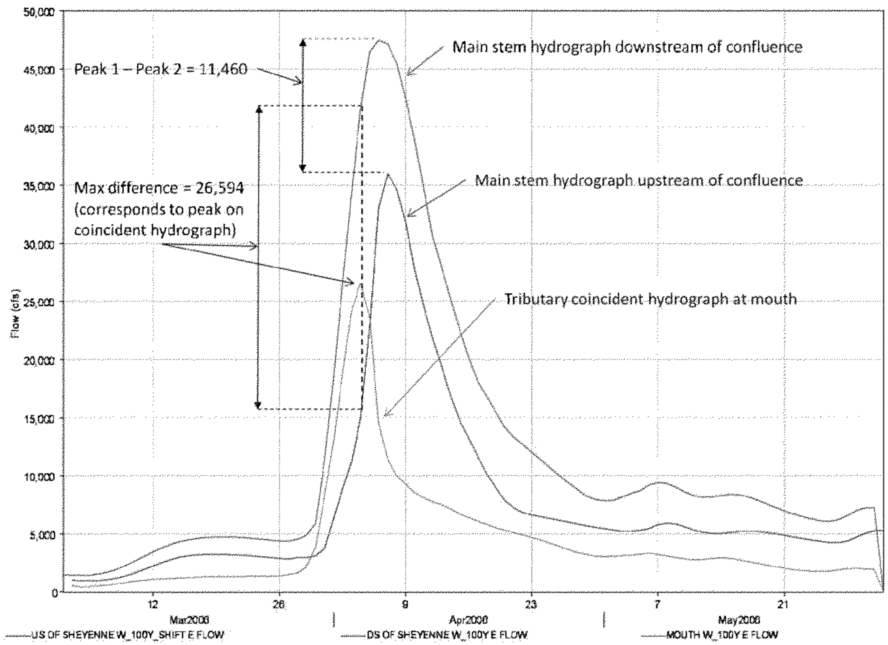
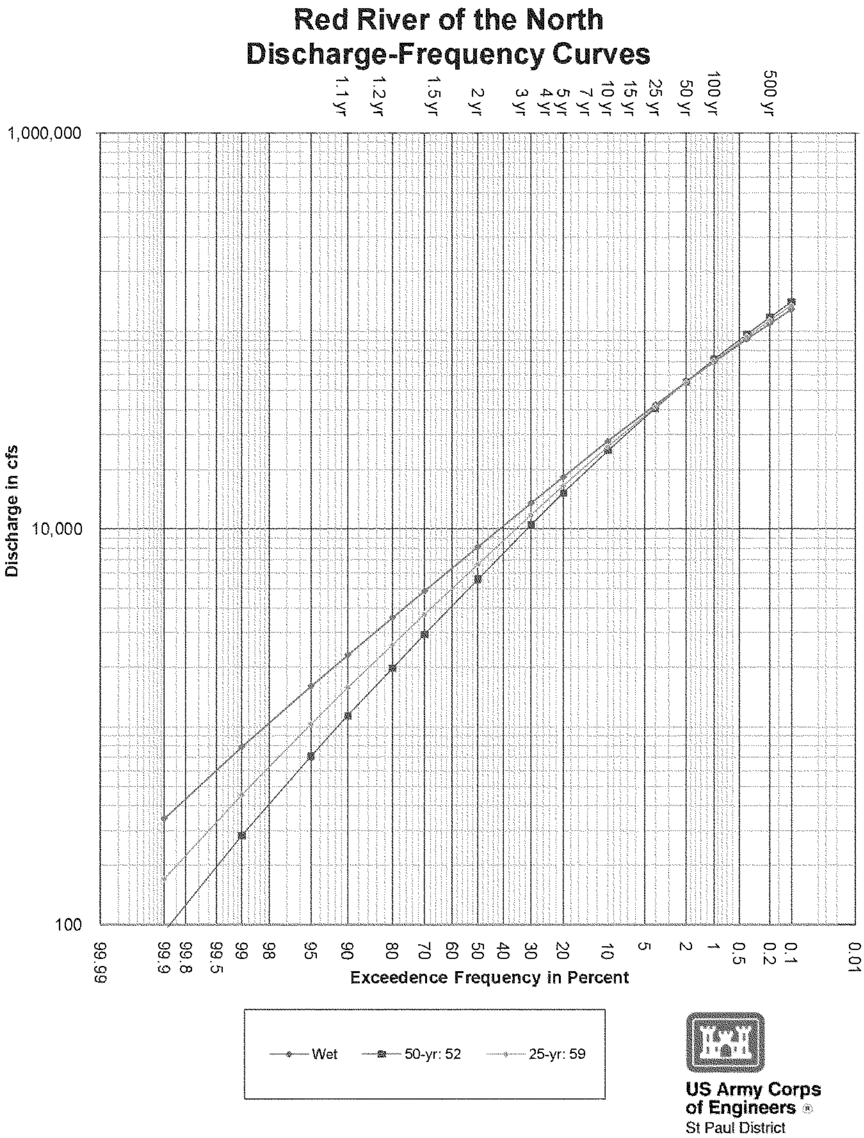


Figure 56. Five % Confidence Limits for WET, 25-yr, & 50-yr Look-Ahead Periods



Appendix A-3
Hydrology

Fargo-Moorhead Metropolitan Area Flood Risk Management

Supplemental Draft Feasibility Report and Environmental Impact Statement

April 2011

US Army Corps of Engineers ®

Prepared by:
U.S. Army Corps of Engineers
St. Paul District
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St. Paul, Minnesota 55101-1678

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Preface

This Appendix describes the development of coincidental flow-frequency curves for major tributaries that reach their confluence with the Red River of the North between Grand Forks, ND and Emerson, Manitoba, Canada. Included in this Appendix is also a description of how annual instantaneous peak flow-frequency curves were determined for the WET portion (1942-2009) for three locations along the mainstem of the Red River of the North: Oslo, MN, Drayton, ND, and Emerson, Manitoba Canada. By interpolating between the adopted flow-frequency curves for the mainstem of the Red River, utilizing the coincidental flow-frequency curves for the tributaries, flow-frequency values could be determined for ungaged locations along the mainstem of the Red River. Flow-frequency values could then be utilized to develop balanced hydrographs patterned after the 2006 Spring Flood Event. This Appendix also includes a justification for selecting the 2006 event as the pattern event for the study.

1. Analysis for Halstad to Grand Forks

1.1 FLOW FREQUENCY CURVES BETWEEN HALSTAD & GRAND FORKS

This section summarizes flow-frequency analysis conducted downstream of Halstad, Minnesota to Grand Forks, North Dakota and balanced hydrographs generated at computation points along the mainstem of the Red River of the North between Halstad, MN and Thompson, ND. A schematic of this reach of the Red River of the North can be found in **Figure 1**. All coincident flow records contained in this report are based on the 1988 USACE *Timing Analysis*. All analysis carried out in this phase of the study is for the WET portion of the period of record from 1942 to 2009.

1.1.1 Coincidental Flows for the Goose River

Coincidental flows from the Goose River tributary for corresponding peak flows on the Red River of the North at Halstad are derived from the mean daily flow recorded by USGS gage 05083000 located at Hillsboro, North Dakota. The period of record associated with the mean daily flow record at the Hillsboro gage is 1931 to 2011. For this analysis only the WET portion (1942-2009) of the period of record was used for analysis. It is assumed that coincident flows at Hillsboro occur on the same day as the instantaneous peak at Halstad. The Hillsboro gage is located on the Goose River upstream of its confluence with the Red River. **Table 1** lists the coincident flow data series.

Table 1. Goose River @ Hillsboro WET (1942-2009) Coincidental Flow Record

Water Year	Coincidental Flow, cfs	Water Year	Coincidental Flow, cfs
1942	155	1986	417
1943	78	1987	1,310
1944	5	1988	996
1945	135	1989	1,890
1946	214	1990	39
1947	962	1991	12
1948	770	1992	750
1949	1,160	1993	2,160
1950	6,920	1994	484
1951	330	1995	1,450
1952	149	1996	3,830
1953	260	1997	4,180
1954	132	1998	110
1955	523	1999	5,450
1956	350	2000	1,600
1957	15	2001	1,790
1958	36	2002	2,630
1959	5	2003	235
1960	1,220	2004	4,630
1961	16	2005	4,280
1962	154	2006	2,410
1963	12	2007	1,110
1964	185	2008	170
1965	4,410	2009	2,860
1966	1,660		
1967	2,540		
1968	233		
1969	2,150		
1970	2,670		
1971	647		
1972	297		
1973	758		
1974	3,050		
1975	92		
1976	997		
1977	24		
1978	1,690		
1979	12,000		
1980	548		
1981	4		
1982	847		
1983	101		
1984	1,400		
1985	24		

[illegible]

The flow-frequency curve for the WET portion (1942-2009) of the period of record at Hillsboro is developed using the observed coincidental flows at Hillsboro. A graphical curve can be fit to coincident peak flow data, plotted using the Weibull plotting position. The graphical curve can be found in **Figure 2**.

The frequency curve values at Hillsboro have to be transferred to the confluence of the Goose River with the Red River. This is done using general relations methodology. This technique uses a drainage area ratio relating the drainage area at Hillsboro to the drainage area associated with the confluence of the Goose River with the Red River. This drainage area ratio is raised to an exponent based on the logarithmic relationship between the WET instantaneous annual peak flow-frequency curves at Hillsboro and Portland and their associated drainage area ratio. As can be seen in **Figure 1**, USGS gage 05065500 near Portland, ND is located on the Goose River upstream of Hillsboro.

Analytical flow-frequency curves at Hillsboro and Portland are generated using a weighted skew value based on station skew and a regional skew of -0.4 and a MSE of 0.302 (source: Plate I of Bulletin 17b). The analytical curves are computed in HEC-SSP and plots are generated using the median plotting position. Since the USGS gage at Portland has a relatively short period of record (1942-1988) it is necessary to augment the flow-frequency analysis at Portland by carrying out a two station comparison with the Hillsboro gage. The resulting flow-frequency values, as well as the resulting exponent can be found in **Table 2.**

Table 2 contains the values required to transfer coincidental flows from Hillsboro to the confluence of the Goose River with the Red River for the WET flow-frequency curve.

Table 2. Goose River- Coincidental Flow-Frequency Curve- WET Analysis (1942-2009)

[illegible]	[illegible] (cfs)	[illegible] (cfs)	[illegible]	WET Flow Frequency [illegible] Hillsboro Coin. Peak Discharge[1] (cfs)	Peak Discharge at the Confluence[1,2] (cfs)
[illegible]	21,453	18,300	0.16	13,000	13,125
[illegible]	17,975	13,900	0.26	10,500	10,663
1	15,525	11,025	0.33	9,000	9,180
2	12,687	8,501	0.41	7,800	7,990
5	9,274	5,685	0.50	5,550	5,716
[illegible]	6,801	3,928	0.56	4,000	4,134
[illegible]	4,480	2,470	0.60	2,300	2,384
[illegible]	1,760	958	0.61	630	653
	Hillsboro	Portland	Goose R. Mouth	[1] Exponent (e) = Log ($Q_{Hillsboro}$/$Q_{Portland}$) / Log ($DA_{Hillsboro}$/$DA_{Portland}$)	
DA [illegible]	1,093	[illegible]	1,106	[2] $Q_{confluence}$ = $Q_{Hillsboro}$ * (DA_{Conf}/$DA_{Hillsboro}$)^e	

[illegible]

1.1.2 Coincidental Flows for the Marsh River

Coincidental peak flows from the Marsh River tributary for corresponding peak flows on the Red River at Halstad, MN are derived from mean daily flows recorded by USGS gage 05067500 near Shelly, MN. The period of record for the Shelly gage is 1944-2011. Only the period of record from 1944 to 2009 is utilized for the WET analysis. The Shelly gage is located upstream of the confluence of the Marsh River with the Red River. It is assumed that the coincident peak at Shelly occurs on the same day as the instantaneous peak at Halstad. **Table 3** lists the coincident flow data series.

Table 3. Marsh River @ Shelly, WET (1944-2009) Coincidental Flow Record

Water Year	Coincidental Flow, cfs	Water Year	Coincidental Flow, cfs
1944	905	1990	13
1945	773	1991	8.5
1946	661	1992	300
1947	3,190	1993	160
1948	950	1994	580
1949	160	1995	814
1950	4,640	1996	1,700
1951	2,070	1997	3,000
1952	654	1998	500
1953	128	1999	1,380
1954	365	2000	1,130
1955	210	2001	1,200
1956	912	2002	1,180
1957	180	2003	278
1958	38	2004	1,690
1959	4.8	2005	875
1960	153	2006	2,470
1961	40	2007	892
1962	359	2008	240
1963	12	2009	1,310
1964	393		
1965	480		
1966	720		
1967	206		
1968	17		
1969	490		
1970	926		
1971	580		
1972	1,220		
1973	182		
1974	2,140		
1975	136		
1976	774		
1977	Missing		
1978	2,220		
1979	2,200		
1980	413		
1981	175		
1982	329		
1983	238		
1984	Missing		
1985	1,120		
1986	1,280		
1987	90		
1988	150		
1989	1,900		

The flow-frequency curve for the WET portion (1942-2009) of the flow record at Shelly is developed using the observed coincident flows. A graphical curve can be fit to the coincident peak flow data plotted using the Weibull plotting position. The graphical curve can be found in **Figure 3.**

The frequency curve at Shelly has to be transferred to the confluence of the Marsh River with the Red River. This is done using general relations methodology. This technique uses a drainage area ratio relating the drainage area at Shelly to the drainage area associated with the confluence of the Marsh River with the Red River. This drainage area ratio is raised to an exponent based on the analysis done between the Portland and Hillsboro gages on the Goose River.

Table 4 contains the values used to transfer flows from Shelly to the confluence of the Marsh River with the Red River for the WET flow-frequency curve. The values corresponding to the Wet Flow-Frequency Curve for Coincident Flows at the mouth of the Marsh River can also be found in **Table 4**.

Table 4. Marsh River- Coincidental Flow-Frequency Curve- WET Analysis (1942-2009)

% Chance Exceedance	Exponent[1]	WET (1942-2009) Flow-Frequency Curve: Shelly Coin. Peak Discharge[1] (cfs)	WET (1942-2009) Flow-Frequency Curve: Peak Discharge at the Confluence[2] (cfs)
0.2	0.16	5,300	5,782
0.5	0.26	5,000	5,419
1	0.33	4,500	4,990
2	0.41	3,800	4,309
5	0.50	2,900	3,382
10	0.56	2,200	2,614
20	0.60	1,600	1,929
50	0.61	590	712
	Shelly	Marsh R. Mouth	[1] Exponent (e) = Log ($Q_{[illegible]}/Q_{Portland}$) / Log ($DA_{[illegible]}/DA_{Portland}$)
DA (sq mi) =	220[3]	300[3]	[2] $Q_{[illegible]} = Q_{[illegible]} \cdot (DA_{[illegible]}/DA_{[illegible]})^e$

[illegible]

1.1.3 Coincidental Flows for the Sand Hill River

Coincidental peak flows from the Sand Hill River tributary for corresponding peak flows on the Red River at Grand Forks are derived from the mean daily flows recorded at USGS gage 05069000 at Climax, MN. The period of record associated with the mean daily flow record at

Climax, MN is 1943 to 2011. Only the portion of the period of record from 1943 to 2009 is adopted for the WET analysis. The Climax gage is located upstream of the confluence of the Sand Hill River and the Red River. It is assumed that the coincident peak at Climax occurs two days before the peak at Grand Forks. **Table 5** lists the coincident flow data series.

Table 5. Sand Hill River @ Climax, WET (1943-2009) Coincidental Flow Record

Water Year	Coincidental Flow, cfs	Water Year	Coincidental Flow, cfs
1943	621	1988	550
1944	60	1989	2,300
1945	378	1990	200
1946	320	1991	65
1947	1,790	1992	120
1948	1,600	1993	1,250
1949	240	1994	1,120
1950	2,240	1995	600
1951	1,000	1996	4,230
1952	233	1997	2,000
1953	102	1998	1,410
1954	400	1999	3,300
1955	500	2000	700
1956	1,260	2001	1,600
1957	450	2002	3,360
1958	112	2003	380
1959	210	2004	1,500
1960	250	2005	913
1961	110	2006	3,530
1962	523	2007	906
1963	180	2008	206
1964	477	2009	2,800
1965	3,700		
1966	4,120		
1967	608		
1968	590		
1969	3,850		
1970	421		
1971	1,110		
1972	1,860		
1973	640		
1974	1,670		
1975	280		
1976	1,130		
1977	65		
1978	2,900		
1979	3,230		
1980	745		
1981	63		
1982	300		
1983	483		
1984	1,500		
1985	Missing		
1986	1,300		
1987	400		

The flow-frequency curve for the WET portion (1942-2009) of the period of record at Climax is developed using the observed coincidental flows at Climax. A graphical curve can be fit to the coincident peak flow data using the Weibull plotting position. The graphical curve can be found in **Figure 4**.

The frequency curve at Climax has to be transferred to the confluence of the Sand Hill River with the Red River. This is done using the general relations methodology. This technique uses a drainage area ratio relating the drainage area at Climax to the drainage area associated with the confluence of the Sand Hill River with the Red River. This drainage area ratio is raised to an exponent based on the analysis done between the Portland and Hillsboro gages on the Goose River.

Table 6 contains the values used to transfer flows from Climax to the confluence of the Sand Hill River with the Red River for the WET flow-frequency curve. The values corresponding to the Wet Flow-Frequency Curve for Coincident Flows at the mouth of the Sand Hill River can also be found in **Table 6**.

Table 6. Sand Hill River- Coincidental Flow-Frequency Curve- WET Analysis (1942-2009)

% Chance Exceedance	Exponent[1]	WET (1942-2009) Flow Frequency Curve	
		Climax Coin. Peak Discharge[2] (cfs)	Peak Discharge at the Confluence[2] (cfs)
[illegible]	0.16	5,100	5,119
[illegible]	0.26	4,950	4,980
1	0.33	4,800	4,838
2	0.41	4,300	4,341
5	0.50	3,850	3,895
[illegible]	0.56	3,300	3,343
[illegible]	0.60	2,100	2,130
[illegible]	0.61	700	710
	Climax	Sand Hill R. Mouth	[1] Exponent (e) = Log ($Q_{Hillsboro}/Q_{Portland}$)/ Log ($DA_{Hillsboro}/DA_{Portland}$)
DA (sq mi)	420	430	[2] $Q_{Confluence} = Q_{Climax} * (DA_{Conf}/DA_{Climax})^e$
[illegible]			

1.1.4 Coincidental Flows for the Red Lake River

Coincidental peak flows from the Red Lake River tributary for corresponding peak flows on the Red River at Grand Forks are derived from mean daily flows recorded at USGS gage 05079000 at Crookston, MN, located upstream of the confluence of the Red Lake River and the Red River. The period of record associated with the Crookston gage is 1901-2011. Only the portion of the period of record from 1942-2009 is adopted for WET analysis. It is assumed that the coincident peak at Crookston occurred one day before the peak at Grand Forks. **Table 7** lists the coincident flow data series.

Table 7. Red Lake River @ Crookston, WET (1942-2009) Coincidental Flow Record

Water Year	Coincidental Flow, cfs[1]	Water Year	Coincidental Flow, cfs
1942	5,500	1987	4,000
1943	6,080	1988	2,100
1944	4,420	1989	4,400
1945	8,910	1990	700
1946	7,630	1991	1,030
1947	7,200	1992	1,600
1948	8,000	1993	3,440
1949	6,000	1994	10,900
1950	22,200	1995	9,060
1951	7,440	1996	21,400
1952	3,520	1997	24,500
1953	1,130	1998	8,090
1954	4,010	1999	14,000
1955	6,990	2000	5,950
1956	12,300	2001	11,500
1957	9,490	2002	9,870
1958	3,110	2003	4,110
1959	3,600	2004	5,700
1960	3,320	2005	7,630
1961	1,310	2006	16,700
1962	9,830	2007	7,770
1963	5,380	2008	3,160
1964	5,020	2009	10,800
1965	15,700		
1966	19,900		
1967	11,100		
1968	3,950		
1969	14,800		
1970	11,500		
1971	11,000		
1972	14,300		
1973	3,050		
1974	12,300		
1975	8,840		
1976	7,100		
1977	800		
1978	15,300		
1979	15,100		
1980	4,000		
1981	5,860		
1982	3,400		
1983	3,960		
1984	4,700		
1985	5,110		
1986	11,000		

The flow-frequency curve for the WET portion (1942-2009) of the POR at Crookston is developed using the observed coincidental flows at Crookston.

Red Lake Dam is located upstream of Crookston, MN on the Red Lake River approximately 196 river miles above the mouth of the Red Lake River. Red Lake Dam impounds the Upper and Lower Red Lakes. The two lakes are connected by a small strait known as "the narrows." The Upper and Lower Lakes provide flood control storage for the Red Lake River and subsequently the Red River of the North watersheds. Available storage for flood runoff is about 1,010,000 acre-feet. During flood events the Red Lake reservoir stores as much runoff as necessary, releasing between 0 and 1,000 cfs depending on downstream conditions. During the 2009 flood event releases from the reservoir were held under 250 cfs between 21 March 2009 and 15 May 2009. The Red Lake River peaked at Crookston on the 25th of March and the Red River peaked at Grand Forks on the 1st of April 2009.

The drainage area for Upper and Lower Red Lake is 1,950 square miles. According to the USGS the 1, 950 square miles in the headwaters of the Red Lake River is completely controlled by the dam outlet of Lower Red Lake. During Flood events flow from this drainage area is essentially cut off from reaching the USGS gage at Crookston and can be considered non-contributing area.

A graphical curve can fit to the coincident peak flow data at Crookston using the Weibull plotting position. The graphical curve can be found in **Figure 5**. By carrying out flow-frequency analysis graphically any regulatory effects caused by Red Lake Dam are accounted for.

The flow-frequency curve at Crookston has to be transferred to the confluence of the Red Lake River with the Red River. This is done using general relations methodology. This technique uses a drainage area ratio relating the drainage area at Crookston to the drainage area associated with the confluence of the Red Lake River with the Red River. This drainage area ratio is raised to an exponent based on the analysis done between the Portland and Hillsboro gages on the Goose River.

Table 8 contains the values used to transfer flows from Crookston to the confluence of the Red Lake River with the Red River for the WET flow-frequency curve. The values corresponding to the Wet Flow-Frequency Curve for coincident flows at the mouth of the Red Lake River can also be found in **Table 8**. The drainage area listed in the table for Crookston and the mouth of the Red Lake River is the area below Red Lake Dam. This is based on the assumption that during large flood events when the coincident peaks are occurring on Red Lake River, minimal flows are being released from the dam.

Table 8. Red Lake River- Flow Frequency Curve- WET Analysis (1942-2009)

		WET (1942-2009) Flow Frequency Curves	
% Chance Exceedance	Exponent	Crookston Coin. Peak Discharge[1] (cfs)	Peak Discharge at the Confluence[2] (cfs)
0.2	0.16	30,000	30,659
0.5	0.26	28,000	28,999
1	0.33	26,000	27,197
2	0.41	25,000	26,406
5	0.50	20,050	21,437
10	0.56	17,000	18,325
20	0.60	13,000	14,102
50	0.61	6,800	7,379
	Crookston	Red Lake R. Mouth	[1] Exponent (e) = Log ($Q_{Hillsboro}$/$Q_{Portland}$)/ Log ($DA_{Hillsboro}$/$DA_{Portland}$)
DA (sq mi)	3,320	3,800	[2] $Q_{confluence}$ = $Q_{Crookston}$ * (DA_{Conf} / $DA_{Crookston}$)^e
[illegible]			

1.1.5 Rebalancing the Hydrographs Downstream of Halstad

The summation of the flow-frequencies at the confluences of the major tributaries along the Red River with the gaged flow-frequency values at Halstad is greater than the gaged based flow-frequency curve downstream at Grand Forks. The adopted analysis relies heavily on the assumption that the travel time/ lag time between recorded flows on the tributaries and when they reach a location on the Red River is the same for every event. This discrepancy could be due to the variability associated with the lag time in determining coincident peaks on the tributaries.

Results can be rebalanced by evenly redistributing the difference in flows at each exceedance interval between Halstad and Grand Forks between the major tributaries along the Red River using drainage area ratios. These revised flow-frequency curves are transferred back to gaged locations along the tributaries and re-plotted to ensure they are comparable to the original graphical curves generated at these locations. The re-plotted values were smoothed out where necessary to resemble the characteristics of the original curves. The curves are displayed in **Figure 6** through **Figure 9**.

Adjusted flow-frequency curve values are significantly less than the data based flow-frequency curves for the Sand Hill and Red Lake Rivers. This is reasonable because according to the National Weather Service Office of Hydrologic Development backwater effects are known to occur on tributaries located along this reach of the Red River of the North. The Red River of the North has a mild slope in the Grand Forks area (~0.5 ft/mi). Mild gradients may cause the river to experience backwater effects. As a result of backwater effects flow gets pushed upstream the tributaries causing a stage increase on the tributary at a time when the river discharge was actually falling (hysteresis).

During large events at Climax and Crookston USGS data is estimated from a stage discharge rating curve. According to the 2009 Water-Data Report estimated daily discharges are "poor." This is most likely because a rating curve relationship is being used to estimate flow from stage. Since the stage is likely high due to backwater effects the rating curve relationship will over estimate the corresponding flow.

1.1.6 Flow-Frequency Curves at Un-gaged Locations

Discharge-frequencies for the reach between Halstad and Grand Forks are based primarily on interpolations between adopted discharge-frequencies at Halstad and Grand Forks and the adopted coincidental flow-frequencies from the Goose River, Marsh River, Sand Hill River and Red Lake River. Flows are estimated between Halstad and Grand Forks using a drainage area ratio. For the 2 and 10 year events the drainage area ratios are raised to exponents of 1.055 and 0.174, respectively. The flow-frequency values can be found in **Table 9**.

Table 9- Flow-Frequency values for ungaged locations between Halstad and Grand Forks

Red River of the North Mainstem Flow-Frequency Analysis WET Analysis (1942-2009) Flow Frequency Values (cfs)									
LOCATION	DA	2-YR	5-YR	10-YR	20-YR	50-YR	100-YR	200-YR	500-YR
Grand Forks	20,015	23,295	42,139	56,354	70,956	91,026	106,838	123,201	145,675
d/s Red Lake	200,15	23,295	42,139	56,354	70,956	91,026	106,838	123,201	145,675
Red Lake Coinc.	3,800	7,379	11,604	13,399	15,437	18,128	20,073	22,200	24,595
u/s Red Lake	16,215	15,916	30,535	42,955	55,519	72,898	86,765	101,001	121,080
Thompson	16,095	15,792	30,535	42,899	55,519	72,898	86,765	101,001	121,080
d/s Sand Hill River	16,015	15,709	30,535	42,862	55,519	72,898	86,765	101,001	121,080
Sand Hill River Coinc.	430	763	1,801	2,700	3,451	4,000	4,226	4,367	4,532
u/s Sand Hill River	15,585	14,946	28,734	40,162	52,068	68,898	82,539	96,634	116,548
d/s Marsh River	15,375	14,734	28,734	40,067	52,068	68,898	82,539	96,634	116,548
Marsh River Coinc.	150	712	1,511	2,420	3,145	3,996	4,709	5,151	5,543
u/s Marsh River	15,225	14,022	27,223	37,648	48,922	64,902	77,830	91,484	111,005
d/s Goose River	15,225	14,022	27,223	37,648	48,922	64,902	77,830	91,484	111,005
Goose River Coinc.	1,160	657	1,964	2,650	3,908	5,596	7,032	8,612	11,292
u/s Goose River	14,065	13,365	25,259	34,997	45,014	59,306	70,798	82,872	99,713
Halstad	13,775	13,074	25,259	34,871	45,014	59,306	70,798	82,872	99,713

1.2 BALANCED HYDROGRAPHS BETWEEN HALSTAD & THOMPSON

Balanced hydrographs are developed at all pertinent computation points located on the reach of the Red River of the North between Halstad and Thompson, ND in support of the unsteady RAS model. Hydrographs are generated for the 0.2-, 0.5-, 1-, 2-, and 10-percent exceedance frequency events for the WET portion of the period of record.

Coincidental balanced hydrographs are required for the confluences of the Goose River, Marsh River, Sand Hill River and Red Lake River with the Red River of the North. Balanced hydrographs on the main stem of the Red River of the North are required upstream and downstream of each of the tributaries, as well as at Thompson, ND.

The Hydrologic Engineering Center's Flood Hydrograph Package, HEC-1, is used to construct balanced hydrographs using specified 1, 3, 7, 15 and 30-day volumes and a pattern event. Flood volume duration analysis provides for the volume at each duration and specified frequency. For the Fargo-Moorhead Metro Feasibility Study the 2006 Spring Flood Event has been adopted as the pattern event.

Coincident flood volume frequency curves are derived at the mouths of the tributaries and at specified locations on the mainstem. This is done by assuming the same proportional change in flood volume at a given duration as at that duration for a hydrologically similar gaged location.

1.2.1 Pattern Event Hydrograph

To develop balanced hydrographs along the mainstem of the Red River of the North, as well as at the confluence of its tributaries it is first necessary to identify an event hydrograph which can be used as a pattern for the balanced hydrographs. The pattern event helps establish the shape and timing of the hydrograph. The 2006 pattern event at gaged locations is acquired from USGS daily observed streamflow measurements. The 2006 pattern event at ungaged locations is determined by routing the closest upstream observed 2006 hydrograph downstream to the location of interest and adding in appropriate local flow hydrographs.

To account for the local flow associated with contributing drainage area between computation points along the Red River of the North, it is necessary to develop hydrographs which are representative of this additional flow. Local flow hydrographs are developed by using a reference USGS gage located in a hydrologically similar area. The 2006 event hydrographs at gaged locations can be modified using a drainage area ratio to generate the local flow hydrographs. The reference gages, along with the associated drainage area ratios, are listed in **Table 10**.

Table 10- Reference gages and drainage area ratios.

Ratios for Determining Flow Resulting from Contributing Areas				
Reach	Ref Gage	DA ref Gage	DA Reach	Ratio
[illegible]	Hillsboro	1,093	[illegible]	[illegible]
[illegible]	Hillsboro	1,093	77	0.0704
[illegible]	Shelly	[illegible]	[illegible]	[illegible]
[illegible]	Climax	[illegible]	[illegible]	0.5
[illegible]	Climax	[illegible]	[illegible]	[illegible]
[illegible]	Crookston	[illegible]	[illegible]	0.145

1.2.2 2006 Spring Event Hydrograph Routing

1.2.2.1 Adopted Routing Parameters

The USACE 1988 *Timing Analysis* can be used to develop straddle stagger routing parameters to route the 2006 event hydrograph downstream from Halstad to Thompson. The adopted routing parameters can be found in **Table 11**.

Table 11. Straddle Stagger Routing parameters – Halstad to Thompson.

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Direct Transfer Lag =0, attenuation is negligible		
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Direct Transfer Lag= 0 , attenuation is negligible		
[illegible]	[illegible]	[illegible]	[illegible]

1.2.2.2 2006 Event Routing Calibration

Daily flow data was recorded by USGS gage 05070000 located on the Red River of the North near Thompson, MN for the 2006 event. The data based hydrograph depicted in **Figure 10** at Thompson is compared to the routed 2006 event hydorgraph just downstream of the Sand Hill River. As can be seen in the figure the routed flows downstream of the confluence of the Sand Hill River and the Red River are quite comparable to the actual gage based hydrograph at Thompson. The timing conforms to what might be expected, with both hydrographs peaking on the same day. The routed hydrograph may be underestimating the attenuation slightly, but is still quite accurate.

Routing parameters are based on the timing and attenuation for a typical event for this portion of the Red River. The actual recorded data for the 2006 event conforms to the modeled flows relatively well. Therefore, the 2006 is representative of a typical event and is thus a good pattern event.

The USGS recorded data for the 2006 event at Thompson, MN and Grand Forks, ND is displayed in **Figure 11**. As can be seen from **Figure 11**, the Red River at Grand Forks is peaking prior to the Red River at Thompson. This is unexpected because Grand Forks is downstream of Thompson, and is atypical for this portion of the river as is indicated by **Table 12**.

Table 12- Timing between Grand Forks and Thompson

[illegible]	[illegible]	[illegible]	[illegible]
2004	34,300	25,400	Thompson peaks 1-day before GF
2005	[illegible]	[illegible]	Peak on the Same Day
2006	[illegible]	[illegible]	GF peaks 1-day before Thompson
2007	[illegible]	[illegible]	Peak on the Same Day
2008	[illegible]	[illegible]	Thompson peaks 1-day before GF
2009	[illegible]	[illegible]	Peak on the Same Day

From **Table 12** one can conclude that Thompson usually peaks on the same day or one day prior to Grand Forks. However, in 2006 this was not the case. In 2006 the event hydrograph at Thompson peaks on April 7th, while the hydrograph at Grand Forks peaks on April 6th. The timing at Grand Forks is reflected in **Figure 12** by both the hydrograph generated using USGS observed flow data and the hydrograph developed using straddle stagger routing.

1.2.2.3 Discussion- 2006 Event as Pattern Event

The Red Lake River is a tributary of the Red River of the North that reaches its confluence with the main stem of Red River just upstream of Grand Forks. The routed hydrograph just upstream of the mouth of the Red Lake River on the Red River of the North is displayed in **Figure 13** in comparison to the observed event hydrograph at Thompson. At this point the timing still seems to be typical, with the Red River peaking just upstream of the Red Lake River one day after peaking at Thompson.

Based on this analysis, it can be concluded that the magnitude of inflows from the Red Lake River caused the timing on the main stem at Grand Forks to be atypical. The timing of the 2006 event is atypical for the Red Lake River and the Red River because the routed curve and the USGS curve yield similar curves. Thus, it must be the magnitude of the flow from the Red Lake River that is causing the Red River to peak earlier than what would be expected for a typical event.

The 2006 event at Oslo peaks on the same day as the peak at Grand Forks. Based on the timing that took place during other flood events as listed in **Table 13**, the Oslo timing of the peak at Oslo with respect to the peak at Grand Forks is reasonable.

Table 13- Timing between Grand Forks and Oslo

WY	Time Lag Between Grand Forks and Oslo (days)
2003	2
2004	0
2005	1
2006	0
2007	1
2008	1
2009	0
1969	3
2001	2
1996	1
1997	5

The timing of the 2006 event between Grand Forks (just downstream of the mouth of the Red Lake River) and Oslo is appropriate, however the magnitude of inflow from the Red Lake River is atypical and thus, the timing of the peak at Grand Forks arrives 2 days early.

No event selected based on observed data will conform completely to what is considered a "typical" flood event in the Red River Basin. Using this reach as a case study it is observed that between Halstad and the Red Lake River and between Grand Forks and Oslo the 2006 event accurately models a typical event on the Red River, but at Grand Forks the timing is atypical as a result of flow coming from the Red Lake River. Because the 2006 event mirrors the average timing and attenuation on the Red River for the majority of the river's reaches it is still appropriate to use it as a pattern event even if it doesn't conform exactly to what is considered typical at a few locations.

1.2.3 Volume Duration Analysis for Coincident Flows

The methodology used for points of interest upstream of Halstad involved using a regression between the mean daily annual peak flow-frequency curve and the annual instantaneous peak flow-frequency curve. In this stage of the study it was decided that it would be more appropriate to directly adopt the coincident flow-frequency curve as the 1-day duration frequency curve. As was done previously, the volume duration curves at other durations were derived by assuming the same proportional change in flow volume for each duration, as for the WET flood volume frequency curves at the hydrologically similar gaged locations. The hydrologically similar location identified for each point of interest and the method used to produce to the volume duration curve is listed in **Table 14**.

Table 14. Hydrologically similar location/ methodology used to produce balanced hydrographs.

Location	River	Volume Type	Hydrologically Similar Location used for generating Fixed Volume Frequency Curve or alternate method used to obtain Balanced hydrograph
Gaged			
Hillsboro	Goose R.	Coincidental	Hillsboro Coincidental Peak with Halstad- No Shift
Shelly	Marsh R.	Coincidental	Shelly Coincidental Peak with Halstad- No Shift
Climax	Sand Hill R.	Coincidental	Climax Coincidental Peak with Grand Forks- +2 day Shift
Crookston	Red Lake R.	Coincidental	Crookston Coincidental Peak with Grand Forks- +1 day Shift
US & DS Goose R.	RRN	Mainstem	Halstad
US & DS Marsh R.	RRN	Mainstem	Halstad
US & DS of Sand Hill R.	RRN	Mainstem	Grand Forks
US & DS of Red Lake R.	RRN	Mainstem	Grand Forks

2. FLOW-FREQUENCY ANALYSIS DOWNSTREAM OF GRAND FORKS

This section contains flow-frequency analysis for the WET portion of the period of record (1942-2009) for the following locations located on the mainstem of the Red River of the North: Oslo, MN, Drayton, ND, and Emerson, Canada.

2.1 Initial Flow-Frequency Analysis

2.1.1 Oslo, MN

As is displayed in **Table 15**, there are only 42 years of instantaneous peak flow data between 1942 and 2009 for the USGS gage at Oslo.

Table 15. Annual Inst. Peak Flows at Oslo- WET Analysis (1942-2009)

Date	Flow (cfs)	Date	Flow (cfs)
1-Apr-42	11,900	8-Apr-88	11,500
13-Apr-43	31,500	14-Apr-89	33,500
26-Mar-45	34,000	5-Apr-90	4,900
22-Apr-47	33,800	10-Jul-91	5,200
17-Apr-48	41,400	15-Mar-92	8,200
18-Apr-49	18,700	7-Apr-93	28,100
10-May-50	63,000	13-Jul-94	26,600
12-Apr-51	24,800	1-Apr-95	35,000
21-Apr-52	24,800	22-Apr-96	59,200
25-Jun-53	14,900	21-Apr-97	120,000
15-Apr-54	9,790	22-Mar-98	29,000
10-Apr-55	16,400	3-Apr-99	53,000
21-Apr-56	22,500	29-Jun-00	31,000
2-Jul-57	14,900	15-Apr-01	51,000
10-Jul-58	7,890	15-Jul-02	34,000
7-Apr-59	7,200	30-Jun-03	16,500
12-Apr-60	17,100	1-Apr-04	36,000
4-Apr-66	59,000	19-Jun-05	36,100
19-Apr-69	56,900	6-Apr-06	77,600
12-Apr-78	36,200	25-Jun-07	37,200
20-Mar-85	17,800	17-Jun-08	18,000
3-Apr-86	30,000	1-Apr-09	80,600
30-Mar-87	18,500		

Because the flow record at Oslo is missing twenty-three years of record, a two station comparison is carried out between the USGS gage at Oslo and the USGS gage at Drayton. Based on this two station comparison the initial statistics at Oslo are adjusted to the values displayed in **Table 16**.

Table 16. Adjusted Statistics based on Oslo two-station comparison

	Statistics	
	Original	Adjusted
Length of Record (N)	45	66
Mean (X)	4.40	4.37
Standard Deviation (S)	0.319	0.331

An analytical flow-frequency analysis can then be carried out using the Hydraulic Engineering Center's Statistical Software Package (HEC-SSP). A Log Pearson Type Three Distribution, adjusted statistics (as defined in **Table 16**) and station skew are utilized to generate the flow-frequency curve.

2.1.2 Drayton, ND

The instantaneous annual peak flow record at Drayton as acquired from the USGS website is displayed in **Table 17**. Using this data, an analytical flow-frequency analysis can be carried out in HEC-SSP by applying a Log Pearson Type Three Distribution to the data. In this stage of analysis station skew is utilized.

Table 17. USGS annual instantaneous peak flow record at Drayton, WET Analysis (1942-2009)

Date	Flow (cfs)	Date	Flow (cfs)
7-Apr-42	21,900	21-May-85	17,700
17-Apr-43	28,700	7-Apr-86	29,700
18-Apr-44	12,300	7-Apr-87	27,600
2-Apr-45	24,600	7-Apr-88	13,900
30-Mar-46	23,000	17-Apr-89	41,800
28-Apr-47	29,300	7-Apr-90	5,080
21-Apr-48	57,000	11-Jul-91	4,940
13-Apr-49	27,900	16-Mar-92	8,800
12-May-50	86,500	14-Aug-93	27,600
15-Apr-51	24,600	6-Apr-94	27,900
25-Apr-52	23,900	1-Apr-95	37,800
26-Jun-53	14,700	25-Apr-96	61,300
15-Apr-54	11,100	21-Apr-97	124,000
11-Apr-55	18,000	24-May-98	28,400
27-Apr-56	28,000	9-Apr-99	39,500
4-Jul-57	14,100	30-Jun-00	29,300
12-Jul-58	7,850	17-Apr-01	55,300
8-Apr-59	11,200	18-Jun-02	34,800
14-Apr-60	24,700	2-Jul-03	15,300
31-Mar-61	3,600	2-Apr-04	37,400
24-Apr-62	32,300	21-Jun-05	31,200
12-Apr-63	12,900	16-Apr-06	78,800
26-Apr-64	15,600	25-Jun-07	30,400
22-Apr-65	47,200	17-Jun-08	18,600
8-Apr-66	67,500	5-Apr-09	85,500
8-Apr-67	32,200		
23-Jul-68	12,500		
18-Apr-69	59,000		
28-Apr-70	31,700		
12-Apr-71	23,400		
26-Apr-72	31,100		
25-Mar-73	13,400		
25-Apr-74	43,900		
1-May-75	44,000		
7-Apr-76	27,600		
9-Apr-77	3,400		
16-Apr-78	56,200		
28-Apr-79	92,900		
16-Apr-80	22,400		
5-Jul-81	7,520		
17-Apr-82	35,500		
9-Apr-83	21,300		
5-Apr-84	32,400		

2.1.3 Emerson, Manitoba, Canada

The instantaneous annual peak flow record at Emerson is displayed in **Table 18**. Using this data, an analytical flow-frequency analysis can be carried out in HEC-SSP by applying a Log Pearson Type Three Distribution to the data. In this stage of analysis station skew is utilized.

Table 18. Annual Instantaneous Peak Flow data at Emerson- WET Analysis (1942-2009)

Date	Flow (cfs)	Date	Flow (cfs)
10-Apr-42	27,900	18-Apr-78	50,300
20-Apr-43	29,500	1-May-79	92,400
19-Apr-44	12,300	10-Apr-80	21,700
4-Apr-45	29,400	4-Jul-81	6,110
5-Apr-46	24,100	18-Apr-82	34,000
28-Apr-47	28,400	9-Apr-83	24,600
27-Apr-48	51,800	8-Apr-84	30,200
15-Apr-49	29,200	29-Mar-85	16,700
13-May-50	94,400	7-Apr-86	34,200
15-Apr-51	26,600	9-Apr-87	37,400
24-Apr-52	24,200	8-Apr-88	15,700
28-Jun-53	14,500	23-Apr-89	42,400
17-Apr-54	11,500	10-Apr-90	5,470
10-Apr-55	23,400	12-Jul-91	5,690
26-Apr-56	33,700	4-Apr-92	15,700
8-Jul-57	15,300	17-Aug-93	31,900
12-Jul-58	7,880	8-Apr-94	26,900
10-Apr-59	15,700	2-Apr-95	42,400
13-Apr-60	30,500	26-Apr-96	66,000
30-Mar-61	4,290	26-Apr-97	133,000
25-Apr-62	33,300	12-Mar-98	27,500
13-Apr-63	13,700	12-Apr-99	58,600
25-Jun-64	17,500	2-Jul-00	31,800
25-Apr-65	46,100	25-Apr-01	57,600
11-Apr-66	66,300	18-Jun-02	35,700
30-Apr-67	33,200	3-Jul-03	14,200
28-Jul-68	13,900	7-Apr-04	45,200
26-Apr-69	54,700	7-Apr-05	38,200
30-Apr-70	39,600	13-Apr-06	72,400
16-Apr-71	26,600	4-Apr-07	34,900
23-Apr-72	30,700	19-Jun-08	16,527
27-Mar-73	14,200	18-Apr-09	88,200
28-Apr-74	43,400		
7-May-75	42,700		
7-Apr-76	31,300		
10-Apr-77	4,440		

2.2 Adopted Flow Frequency Curves

The flow-frequency curves generated at Oslo, Drayton, and Emerson are plotted alongside the previously adopted flow-frequency curves at Fargo, Halstad, and Grand Forks. In order to produce a family of nested curves for the mainstem of the Red River, smoothing functions have to be developed and applied to the skew and standard deviation associated with the flow-frequency curves at Oslo, Drayton, and Emerson.

The mean squared error (MSE) associated with the adopted skew is found using the methodology described in Bulletin 17b (Equation 6). The initial statistics, along with the adopted statistics for the flow-frequency curves at Oslo, Emerson, and Drayton, can be found in **Table 19**. The linear relationships used to smooth out the statistics can be found in **Figure 14** and **Figure 15.**

Table 19. Initial and adjusted statistics for the flow-frequency curves Upstream of Grand Forks

	Mean Log	Standard Deviation		Skew		
		Initial	Adopted	Initial	Adopted	MSE
Drayton	4.400	0.327	0.320	-0.511	-0.292	0.094
Emerson	4.431	0.314	0.315	-0.530	-0.291	0.094
Oslo[1]	4.365	0.331	0.325	-0.300	-0.292	0.097

1 The statistics at this station were adjusted based on a two station comparison

The values for station skew at Emerson and Drayton are not used to develop the function used to smooth skew. The station skew values computed from observed data at Emerson and Drayton deviate significantly from the observed trend produced by skew values in the rest of the basin. This can be seen in **Figure 15**.

The adjusted statistics listed in **Table 19** are used to develop the adopted flow-frequency curves at Oslo, Emerson and Drayton. The flow frequency values at these locations can be found in **Table 20**. The corresponding family of curves can be found in **Figure 16**.

Table 20 Adopted Flow-Frequency Curves Downstream of Grand Forks- WET Analysis (1942-2009)

Red River of the North Mainstem Flow-Frequency Analysis WET Analysis (1942-2009)			
Exceedance Frequency in %	Mainstem Locations		
	USGS Gage Site 05083500 at Oslo, MN (cfs)	USGS Gage Site 05092000 at Drayton (cfs)	USGS Gage Site 05102500 at Emerson (cfs)
0.2	153,811	161,486	169,000
0.5	129,950	136,789	143,483
1	112,569	118,757	124,815
2	95,773	101,292	106,697
5	74,459	79,061	83,572
10	58,970	62,847	66,650
20	43,920	47,027	50,081
50	24,056	26,009	27,937
80	12,513	13,674	14,827
90	8,706	9,571	10,434
95	6,381	7,051	7,722
99	3,466	3,869	4,276

3. Balanced Hydrographs: Grand Forks to Drayton

3.1 Grand Forks to Oslo

As can be seen in **Figure 17**, there is one major tributary to the Red River of the North between Grand Forks and Oslo: the Turtle River. Balanced hydrographs are required for upstream of the Turtle River's confluence with the Red River of the North, at the mouth of the Turtle River and at Oslo (which is also assumed to be representative of conditions just downstream of the Turtle River).

3.1.1 Volume Duration Analysis

Developing volume duration curves is the first step in developing balanced hydrographs. A mean daily flow record is required to carry out volume duration analysis. The USGS gage at Oslo only records mean daily flow data during flood events. Because a continuous flow record does not exist for Oslo, the volume duration curve at Oslo has to be developed indirectly.

Volume duration curves at Grand Forks are used to determine the proportional change in volume between the 1-day volume duration curve and the curves corresponding to other durations of interest. The 1-day volume duration curve is equivalent to the adopted flow-frequency curve at a location. The relationship developed at Grand Forks can be applied to the adopted flow-frequency curve at Oslo in order to develop volume duration curves for Oslo.

Because there is no gaged record just upstream of the Turtle River's confluence with the Red River, the flow-frequency curve at the mouth of the Turtle River is found using interpolation. A drainage area ratio raised to an exponent "n" is used to interpolate between the known flow-frequency curves at Oslo and Grand Forks. The "n" values used for this analysis can be found in **Table 21**. The drainage areas used in this analysis are based on the contributing areas found in the Red River FIS study and on the USGS website. The flow-frequency curve representative of conditions upstream of the Turtle River's confluence with the Red River can be found in **Table 21**.

A volume duration curve cannot be developed directly for upstream of the mouth of the Turtle River. Instead, the volume duration curve at Grand Forks is used to determine the proportional change in volume between the 1-day duration (the flow-frequency values) and the other durations. In this way a volume duration relationship is developed for upstream of the mouth of the Turtle River based on the adopted flow-frequency curve at that location.

Table 21. Interpolation Table to find flow-frequency values at ungaged locations – WET Analysis (1942-2009)

Red River of the North Mainstem Flow-Frequency Analysis WET Analysis (1942-2009)									
	Flow-Frequency Values (cfs)								
LOCATION	DA (sq mi)	2-YR	5-YR	10-YR	20-YR	50-YR	100-YR	200-YR	500-YR
USGS Gage Site 05083500 at Oslo, MN	21,105	24,056	43,920	58,970	74,459	95,773	112,569	129,950	153,811
n		0.61	0.78	0.86	0.91	0.96	0.99	1.01	1.02
D/S Turtle River, MN	21,105	24,056	43,920	58,970	74,459	95,773	112,569	129,950	153,811
Mouth of the Turtle River-Coincident Flows	635	547	1,282	1,885	2,524	3,422	4,132	4,867	5,868
U/S Turtle River, MN	20,319	23,509	42,638	57,086	71,935	92,351	108,437	125,083	147,943
USGS Gage Site 05082500 at Grand Forks, ND	20,015	23,295	42,139	56,354	70,956	91,026	106,838	123,201	145,675

3.1.2 Balanced Hydrographs

3.1.2.1 Explicit Derivation of Balanced Hydrographs

Balanced hydrographs are developed at Oslo and just upstream of the mouth of the Turtle River by using HEC-1. To utilize HEC-1, a pattern hydrograph must be identified. The 2006 spring flood event is utilized as the pattern event for this study. The same pattern hydrograph is used for Oslo as for the location just upstream of the mouth of the Turtle River. This assumption can be made because the Turtle River has a relatively small drainage area. As a result of having a small drainage area, the amount of flow entering the Red River from the Turtle River will have little effect on the shape and timing of the hydrograph on the mainstem of the Red River of the North.

No observed daily discharge data is available at the USGS gage located on the Red River of the North at Oslo for the 2006 spring event. USGS mean daily stage data is available for the 2006 spring flood event at Oslo. The National Weather Service (NWS) provided a rating curve relating stage and flow at Oslo, as well as a flow record generated at Oslo using a model. The resources provided by the NWS, USGS mean daily stage data and the adopted USGS annual instantaneous peak flow for 2006 at Oslo can be used to develop a 2006 pattern event hydrograph at Oslo.

The discharge hydrograph produced by the NWS model appears to be a bit flashy. The discharge hydrograph based on the rating curve appears more realistic. A comparison of both hydrographs can be found in **Figure 18** and **Figure 19**. For this reach, the rating curve based discharge data set was utilized as the 2006 pattern event.

By using the 2006 pattern hydrograph, the volume duration relationships and the HEC-1 Software package, balanced hydrographs can be generated for Oslo and just upstream of the mouth of the Turtle River.

3.1.2.2 Implicit Derivation of Balanced Hydrographs

There are only two USGS gages on the Turtle River: one located at Turtle River State Park near Arvilla, ND and one located downstream at Manvel, ND. Neither gage is continuous for the WET portion of the period of record. The instantaneous annual peak flow records at Arvilla and Manvel extend from 1993 to 2009 and 1946 to1982, respectively. Data based flow-frequency curves cannot be generated along the Turtle River. The flow-frequency relationship and corresponding balanced hydrographs at the mouth of the Turtle River have to be developed implicitly. This is done by subtracting the balanced hydrographs developed for the point upstream of the Turtle River from the balanced hydrographs developed at Oslo to produce the balanced hydrographs for the mouth of the Turtle River. A flow-frequency curve can be developed for the mouth of the Turtle River by identifying the peaks of the resulting balanced hydrographs and can be found in **Table 21**.

3.2 Flow Frequency Curves between Oslo and Drayton

There are three significant tributaries that flow into the Red River between Oslo and Drayton: the Forest River, the Snake River and the Park River. The Tamarac River also reaches its confluence the Red River, but due to its relatively small contributing area, a detailed flow analysis is not necessary for the Tamarac River. A schematic describing this portion of the Red River can be found in **Figure 17**. USGS gage data available for the Red River tributaries between Oslo and Drayton is displayed in **Figure 20**. Coincident flow frequency curves are developed for the WET portion of the period of record (1942-2009) at the mouth of each these tributaries as well as for just upstream and downstream of the confluence of the tributaries with the Red River of the North. The adopted flow-frequency curves for these locations are displayed in **Table 22**. Coincident timing is selected based on the the *1988 USACE Timing Analysis*.

Table 22. Adopted Flow-Frequency Curves between Oslo and Drayton- WET Analysis (1942-2009)

Red River of the North Mainstem Flow-Frequency Analysis WET Analysis (1942-2009)									
	Flow-Frequency Values (cfs)								
Location	DA (sq mi)	2-YR	5-YR	10-YR	20-YR	50-YR	100-YR	200-YR	500-YR
USGS Gage Site 05092000 at Drayton	24,670	26,009	47,027	62,847	79,061	101,292	118,757	136,789	161,486
n		1.13	-0.37	-1.20	-1.87	-2.22	-2.28	-2.10	-1.87
D/S Park River, ND	24,100	25,329	47,441	64,630	82,603	10,6697	125,252	143,672	168,702
Park River Coincidental Flows	1,010	550	1,700	2,800	4,300	6,000	7,000	7,500	8000
U/S Park River, ND	23,090	24,779	45,741	61,830	78,303	100,697	118,252	136,172	160,702
D/S Snake River, MN	23,060	24,743	45,763	61,927	78,494	100,989	118,602	136,545	161,094
Snake River Coincidental Flows	950	342	1,174	2,004	2,921	3,912	4,592	5,084	5,694
U/S Snake River, MN	22,110	24,400	44,589	59,923	75,573	97,077	114,010	131,460	155,399
D/S Forest River, ND	22,080	24,363	44,611	60,020	75,765	97,370	114,363	131,836	155,794
Forest River Coincidental Flows	900	210	750	1,300	1,800	2,350	2,700	2,850	3,000
U/S Forrest River, ND	21,180	24,153	43,861	58,720	73,965	95,020	111,663	128,986	152,794
USGS Gage Site 05083500 at Oslo, MN	21,105	24,056	43,920	58,970	74,459	95,773	112,569	129,950	153,811

3.2.1 Forest River Tributary

Coincidental peak flows from the Forest River tributary for corresponding peak flows on the Red River of the North at Oslo are derived from combining the USGS mean daily flow records at USGS gages 05084500 and 0508500 located on the Forest River at Minto, ND. It is assumed that the coincident flows at Minto occurred on the same day as the instantaneous peak at Oslo. This assumption is based on the results of the *Timing Analysis* developed for the Red River Basin by the Corps of Engineers in 1988. **Table 23** lists the coincident flow data series.

Table 23. Forest River at Minto, Coincidental Flow Record, WET Analysis (1942-2009)

Water Year	Coincidental Flows (cfs)[1]	Water Year	Coincidental Flows (cfs)[1]
1942	1,200	1988	200
1943	85	1989	35
1945	214	1990	23
1947	33	1991	12
1948	1,400	1992	150
1949	1,680	1993	199
1950	4,290	1994	60
1951	127	1995	420
1952	48	1996	800
1953	20	1997	1,310
1954	55	1998	31
1955	161	1999	443
1956	709	2000	35
1957	10	2001	413
1958	18	2002	65
1959	260	2003	54
1960	733	2004	1,890
1966	680	2005	188
1969	454	2006	803
1978	551	2007	284
1985	35	2008	65
1986	190	2009	506
1987	650		

[1]Data Based on USGS mean daily flow record

The flow-frequency curve for the WET portion (1942-2009) of the period of record at Minto is developed using the observed coincidental flows at Minto. A graphical curve can be fit to the coincident peak flow data, plotted using the Weibull plotting position. The graphical curve can be found in **Figure 21**.

The frequency curve determined at Minto is assumed to be equivalent to the flow-frequency curve at the mouth of the Forest River. This assumption can be made because Ardoch Dam is located downstream of the Minto gage. Ardoch dam was constructed in 1938. The dam is owned by the Department of the Interior: U.S Fish and Wildlife Service. The dam consists of an earthen structure with a length of 2,500 feet and a maximum discharge of 10,380 cfs. Its storage capacity is 13,630 acre-feet. Normal storage for this dam is 3,939 acre-feet. The dam has a drainage area of approximately 793 square miles. The regulatory effects of Ardoch Dam are assumed to effectively cancel out any added flow that might enter the Forest River between Minto and its confluence with the Red River. The adopted flow-frequency curve at the mouth of the Forest River can be found in **Table 22**.

3.2.2 Snake River

Coincidental peak flows from the Snake River tributary for corresponding peak flows on the Red River of the North at Oslo are derived from the USGS mean daily flow record at the Argyle gage on the Middle River. The USGS gage at Argyle only started recording flows in 1951. The portion of the WET period of record from 1942-1950 is unknown for the Snake River. The Middle River is a tributary of the Snake River. As is displayed in **Figure 20** there are two USGS gages on the mainstem of the Snake River: Alvarado, MN and Warren, MN. Neither gage has a significant period of record.

It is assumed that the coincident flows at Argyle occur one day later then the instantaneous peaks at Oslo. This assumption is based on the results of the *Timing Analysis* developed for the Red River Basin by the Corps of Engineers in 1988. **Table 24** contains the coincident flow data series.

Table 24. Middle River (Snake River Trib.) at Argyle, Coincidental Flow Record- Wet Analysis (1942-2009), USGS gage at Argyle POR: 1951-2009

Water Year	Coincidental Flows (cfs)[1]	Water Year	Coincidental Flows (cfs)[1]
1951	694	1991	74
1952	96	1992	90
1953	5	1993	213
1954	106	1994	72
1955	180	1995	458
1956	716	1996	1,400
1957	224	1997	1,650
1958	542	1998	203
1959	490	1999	1,600
1960	546	2000	175
1966	1,570	2001	748
1969	530	2002	120
1978	950	2003	21
1985	87	2004	562
1986	559	2005	432
1987	400	2006	1,700
1988	261	2007	285
1989	300	2008	83
1990	29	2009	420

[1]Data Based on USGS mean daily flow record

The flow-frequency curve for the WET portion (1942-2009) of the period of record at Argyle is developed using the observed coincidental flows at Argyle. A graphical curve can be fit to the coincident peak flow data, plotted using the Weibull plotting position. The graphical curve can be found in **Figure 22**.

The frequency curve at Argyle must be transferred to the confluence of the Snake River with the Red River. This is done using general relations methodology as described in **Table 25**. This technique uses a drainage area ratio relating the drainage area at Argyle to the drainage area associated with the confluence of the Snake River with the Red River. This drainage area ratio is raised to an exponent based on the relationship between analytically based Annual Instantaneous Flow-Frequency curves for the Minto and Argyle gages. HEC-SSP is used to develop the analytical flow frequency curves at Minto and Argyle, using weighted skew. Regional skew values are acquired from the USGS Generalized skew Coefficient Report published in 1997.

Table 25. Flow Frequency Curve Transferred to the Mouth of the Snake River

Freq	Argyle Peak Q (POR) cfs	Minto Peak Q (POR) cfs	Log(Flow Ratio)/ Log(DA Ratio)	Coin @ Argyle (wet)	Argyle coin @ mouth (wet)
0.2	8,067	21,996	1.13	1,850	8,166
0.5	6,920	16,514	0.98	1,800	6,524
1	6,027	12,958	0.86	1,750	5,434
2	5,119	9,881	0.74	1,700	4,499
5	3,907	6,498	0.57	1,600	3,397
10	2,992	4,422	0.44	1,300	2,317
20	2,091	2,730	0.30	900	1,336
50	939	1,033	0.11	320	368
Snake R	**Argyle**	**Minto**			
DA	Gage DA	Gage DA			
sq. mi.	sq. mi.	sq. mi.			
950	255	620			
Regional Skew:	-0.481	-0.413			

The flow-frequency curve at Argyle must be adjusted significantly in order to transfer the curve to the mouth of the Snake River. It is necessary to further adjust the resulting curve in order to ensure that the adopted flow-frequency curve for the mouth of the Snake River reflects a similar pattern as the other coincidental flow frequency curves developed for the reach of the Red River between Oslo and Drayton. The coincidental flow frequency curves at the mouths of the Forest and the Park Rivers are used to carry out this analysis. A relationship can be developed between flow and drainage area at significant exceedance probabilities for the pertinent coincidental flow-frequency curves. The resulting relationships between exceedance probability, drainage area and discharge are displayed in **Figure 23**. These relationships are used to determine the adopted flow-frequency curve at the mouth of the Snake River. The adopted flow-frequency for the mouth of the Snake River can be found in **Table 22**.

3.2.3 Park River

Coincidental peak flows from the Park River tributary for corresponding peak flows on the Red River of the North at Drayton are derived from the USGS mean daily flow record at the Grafton gage. It is assumed that the coincident flows at Grafton occur three days prior to the instantaneous peak at Drayton. This assumption is based on the results of the *Timing Analysis* developed for the Red River Basin by the Corps of Engineers in 1988. The Grafton gage is located on the Park River, just upstream of its confluence with the Red River.
Table 26 lists the coincident flow data series.

Table 26. Park River @ Grafton, Coincidental Flow Record- WET Analysis (1942-2009)

Water Year	Coincidental Flow (cfs)	Water Year	Coincidental Flow (cfs)
1942	21,900	1976	27,600
1943	28,700	1977	3,400
1944	12,300	1978	56,200
1945	24,600	1979	92,900
1946	23,000	1980	22,400
1947	29,300	1981	7,520
1948	57,000	1982	35,500
1949	27,900	1983	21,300
1950	86,500	1984	32,400
1951	24,600	1985	17,700
1952	23,900	1986	29,700
1953	14,700	1987	27,600
1954	11,100	1988	13,900
1955	18,000	1989	41,800
1956	28,000	1990	5,080
1957	14,100	1991	4,940
1958	7,850	1992	8,800
1959	11,200	1993	27,600
1960	24,300	1994	27,900
1961	3,600	1995	37,800
1962	32,300	1996	61,300
1963	12,900	1997	124,000
1964	15,600	1998	28,400
1965	47,200	1999	59,500
1966	67,500	2000	29,300
1967	32,200	2001	55,300
1968	12,500	2002	34,800
1969	59,000	2003	15,300
1970	31,700	2004	37,400
1971	23,400	2005	31,200
1972	31,100	2006	78,800
1973	13,400	2007	30,400
1974	43,900	2008	18,600
1975	44,000	2009	85,500

*Data Based on USGS mean daily flow record

The flow-frequency curve for the WET portion (1942-2009) of the period of record at Grafton can be developed using the observed coincidental flows at Grafton. A graphical curve is fit to the coincident peak flow data, plotted using the Weibull plotting position. The graphical curve can be found in **Figure 24**. Because Grafton is located close to the mouth of the Park River, it is unnecessary to use general relations to transfer the Grafton flow-frequency curve to the mouth of the Park River. The graphical curve at Grafton is directly adopted as the coincidental flow frequency curve at the mouth of the Park River as displayed in **Table 22**.

3.2.4 Upstream and Downstream Flow-Frequency Analysis

It was necessary to develop flow-frequency curves for points of interest upstream and downstream of the tributaries along the reach between Oslo and Drayton. Flow-frequency analysis at these ungaged locations is developed using drainage area based interpolation between adopted discharge-frequencies at Oslo, Drayton, and the adopted coincidental flow-frequency curves developed at the mouths of the Forest River, Snake River, and Park River. Interpolation is carried out using a drainage area ratio and raised to an exponent 'n' as shown in **Table 22**.

The summation of the inflows coming off the tributaries in conjunction with the flows at Oslo, exceed the downstream flows at Drayton. This implies that flow is being attenuated throughout the reach between Oslo and Drayton. A comparison made between the annual instantaneous peak flow records at Oslo and Drayton indicated that for 34% of the period of record, annual instantaneous peak flows at Oslo exceeded the peak flows at Drayton. This confirms that attenuation occurs between Oslo and Drayton. This is reflected within the adopted flow-frequency curves found in **Table 22**.

3.2.5 Balanced Hydrographs between Oslo and Drayton

3.2.5.1 Pattern Event Hydrograph

The 2006 spring flood event is being utilized as the pattern event for the Fargo-Moorhead Metro Feasibility Study. In order to develop pattern hydrographs for ungaged locations along the Red River reach between Oslo and Drayton, the Hydraulic Engineering Center's Hydrologic Modeling Software package (HEC-HMS) is utilized to route the 2006 Spring Flood Event hydrograph downstream from Oslo to Drayton.

Daily flow values were not continuously recorded for the 2006 event at Oslo. As a result, a hydrograph must be generated at Oslo for the 2006 event. Initially a rating curved provided by the National Weather Service (NWS) was utilized to convert stage values to a mean daily discharge record (this was the methodology used for the reach between Grand Forks and Oslo). Calibration runs in HEC-HMS indicate that the modeled flows that the NWS had also provided produce a better result than the flow record generated using the rating curve. NWS modeled discharges at Oslo for the 2006 event are adopted and routed downstream.

The reach between Oslo and Drayton is broken up into subreaches as described in **Table 27**.

With the exception of two subreaches, straddle stagger routing can be utilized to route the 2006 event at Oslo downstream to Drayton. For the subreaches between the mouth of the Park River and the Snake River and between the Park River and the Tamarac River, a direct lag should be used to route flows. Routing parameters are based on the *USACE 1988 Timing Analysis*. Adopted parameters are displayed in **Table 27**.

Table 27. Routing parameters Oslo to Drayton

HMS Routing Oslo to Emerson				
	Based on Timing Study			
Subreaches	Average (Day)	(min)	Lag (day)	(min)
Oslo to Forest R	5	6000	1.333	1920
Minto to Mouth of Forest R	2	2560	0.500	720
Forest R to Snake R	3	4000	0.556	800
Argyle to Mouth of Snake R	3	4000	0.889	1280
Snake R to Park R	Lag Only		0.333	480
Grafton to Mouth of Park R	2	3200	0.889	1280
Park R to Tamarac R	Lag Only		0.444	640
Tamarac R to Drayton	6	8000	1.111	1600

Routing requires that local inflows be assigned to the subreaches between Oslo and Drayton. Local flows are determined using a drainage area ratio and 2006 observed flows associated with hydrologically similar gaged locations. **Table 28** displays the hydrologically similar references gages, along with the drainage area ratios that can be used to develop the local flows associated with the subreaches between Oslo and Drayton.

Table 28. Local Flow Parameters

Local Area	Reference Gage	DA Ratio
Oslo to US Forest R	Minto (Forest R)	0.12
Minto to Conf Forest R w/ RRN	Minto (Forest R)	0.45
DS Forest R to US Snake R	Minto (Forest R)	0.048
Argyle to Conf Snake R w/ RRN	Argyle (Middle R)	1.32
DS Snake R to US Park R	*Assume Local Flow Negligible*	
Grafton to Conf Park R w/ RRN	Grafton (Park R)	0.45
DS Park R to US Tamarac R	*Assume Local Flow Negligible*	
US Tamarac R to Drayton	Grafton (Park R)	0.82

3.2.5.2 Volume Duration Analysis

To develop balanced hydrographs for ungaged points of interest upstream and downstream of the tributaries along the mainstem of the Red River between Oslo and Drayton, it is necessary to develop volume duration curves at these locations. Volume duration curves cannot be generated directly because no mean daily flow record exists at ungaged sites. To develop these curves, a volume duration curve generated for the gaged location at Drayton is used to determine the proportional change in volume between the 1-day duration (flow frequency values) and the other durations of interest. This proportional change in volume is applied to the adopted flow-frequency curves at the ungaged locations in order to generate the volume duration curves.

Volume duration curves also must be developed at the confluences of the tributaries with the Red River. Because volume duration curves cannot be directly developed for coincidental flows, the volume duration curves at these locations are generated by using volume duration curves generated from gaged locations along the tributaries. The volume duration curves at these gaged locations are used to determine the proportional change in volume between the 1-day duration and other durations of interest. This proportional change in volume is then applied to the adopted flow-frequency curves for the mouths of the tributaries in order to generate the volume duration curves.

The points of interest along the Red River reach between Oslo and Drayton, along with the hydraulically similar site used to generate the volume duration curves, are listed in **Table 29**.

Table 29. Volume Duration Curves for ungaged locations

Location	River	Volume Type	Hydrologically Similar Location used for generating Flood Volume Frequency Curve or alternate method used to obtain Balanced Hydrograph
Oslo	Red River	Main Stem	Grand Forks
Red River US of Forest River	Red River	Main Stem	Drayton
Forest River at Mouth	Red River	Coincidental	Minto
Red River DS of Forest River	Red River	Main Stem	Drayton
Red River US of Snake River	Red River	Main Stem	Drayton
Snake River at Mouth	Red River	Coincidental	Argyle
Red River DS of Snake River	Red River	Main Stem	Drayton
Red River US of Park River	Red River	Main Stem	Drayton
Park River at Mouth	Red River	Coincidental	Grafton
Red River DS of Park River	Red River	Main Stem	Drayton

3.2.5.3 Balanced Hydrographs

The Hydrologic Engineering Center's Flood Hydrograph Package, HEC-1, is used to construct balanced hydrographs using specified 1, 3, 7, 15 and 30-day volumes and a pattern event. Balanced hydrographs are developed at the locations identified in **Table 29** using HEC-1. Flood volume duration analysis provides for the volume at each duration and specified frequency. For the Fargo-Moorhead Metro Feasibility Study the 2006 Spring Flood Event has been adopted as the pattern event.

4. Analysis between Drayton and Emerson

The reach between Emerson and Drayton includes two significant tributaries: the Pembina River and Two Rivers. A schematic of this reach of the Red River can be found in **Figure 25.**

4.1 Red River of the North-Mainstem

4.1.1 Available Data & Hydrologic Properties

According to the USGS, the reach of the Red River of the North between Drayton and Emerson lies in a glacial lakebed. Consequently, the floodplain is relatively flat (less than 0.5- foot drop in elevation per mile). Because of the flat floodplain, shallow river channel, and the river's northerly flow, the timing of spring snowmelt greatly facilitates flooding in this part of basin. Since flows tend to breakout into the floodplains during flood events, significant attenuation of channel flow occurs between Drayton and Emerson. These overland breakouts are evident in the photograph from the 1979 flood event displayed in **Figure 26**.

4.1.2 2006 Event Hydrograph Routing

The USGS recorded 2006 spring flood hydrograph is routed from Drayton to Emerson in order to develop pattern hydrographs at ungaged locations of interest along this reach of the Red River.

As can be seen in **Table 30,** the 2006 event peak flow decreased 7% between Drayton and Emerson. Adopted routing parameters are based on the *U.S Army Corps of Engineers 1988 Timing Study*. The 1948, 1969, 1975 (spring) and 1978 flood events can be used to develop Straddle Stagger routing parameters for the reach. These events are significant because attenuation in the peak between Drayton and Emerson was observed for these years. The peak flow values associated with these locations are recorded in **Table 30.**

Table 30. Comparison between flows at Drayton and Emerson (USGS)

Water Year	Peak Flow at Drayton (cfs)	Peak Flow at Emerson (cfs)	% Total Change in Peak (cfs)
1948	57, 000	51, 800	- 9
1950	86, 000	95, 500	+ 11
1965	47, 200	46, 200	-2
1966	67, 500	66, 800	-1
1969	59, 000	54, 700	-7
1975 (Spring)	44, 000	42, 800	-3
1978	56, 200	50, 600	-9
1979	92, 900	92, 700	0
2006	78, 800	73, 500	-7

The routing parameters associated with each of these four events are modeled using the observed flows at Drayton and the routed flows associated with Two Rivers and the Pembina River. The resulting flows at Emerson are compared to the actual observed flows at Emerson for the 2006 event. The routing parameters associated with the 1975 (spring) event, as displayed in **Table 30**, most closely reproduced the 2006 flood event at Emerson as can be seen in **Table 31.**

Table 31. Straddle Stagger Routing Parameters: Drayton to Emerson

Reach	Average	Lag
Drayton to Two Rivers	13	7
Two Rivers to Emerson (Pembina River)	10	1

DSS-VUE has to be used to carry out straddle stagger routing. The hydrographs have to be averaged (straddle) and lagged (stagger) in two steps in order to preserve the correct timing. The resulting hydrograph at Emerson compared to the hydrograph based on observed flow at Emerson is displayed in **Figure 27**. No local flow is added in because it is assumed that local flow ran off before the peak arrived on the Red River of the North.

4.2 Two Rivers

<u>4.2.1 Available Data & Hydrologic Properties</u>

As can be seen in **Figure 28**, the Two Rivers tributary is made up of three branches: the North Branch, Middle Branch and South Branch.

There are four USGS daily stream flow gages located within the Two Rivers watershed. There is one USGS observed streamflow measurement near the confluence of the Two Rivers with the Red River of the North. Available USGS gage data can be found in **Table 32** and their corresponding geographical locations can be found in **Figure 28**.

Table 32. USGS gages Located within the Two Rivers Watershed

Gage Location	USGS Gage #	Period of Record
South Branch of the Two Rivers at Lake Bronson, MN	05094000	1928- Present
Two Rivers at Hallock, MN	05095000	1911-1943
Two Rivers below Hallock, MN	05095500	1945-1955
North Branch of the Two Rivers near Northcote, MN	05097500	1941- 1951

The two gages near Hallock are located close together on the same branch of the Two Rivers. The recorded flow records at these two locations can be combined in order to create a more complete streamflow record at Hallock. USGS gage 05097500 located near Northcote has a short period of record from 1941 to 1951. Because of its abbreviated flow record, the Northcote gage is not used in this study. The Two Rivers long term gaging station is located on the South Branch of the Two Rivers downstream of Lake Bronson, MN.

On Dec 12, 1991, the USGS took an observed streamflow measurement of 64.2 cfs near the confluence of the Two Rivers with the Red River. It can be assumed that backwater effects from the Red River of North did not effect this measurement. This measurement can be used in calibrating HMS routing of the 2006 event for use as a pattern event for developing balanced hydrographs.

A flow record can be developed for the WET portion of the period of record at Hallock (1942-2009) by developing a linear relationship for the concurrent portion of the period of record between the USGS gage at Lake Bronson and the USGS gage at Hallock. A relatively good correlation exists between the two gages as can be seen in **Figure 29**.

4.2.2 Coincidental Flow Frequency Analysis

Coincident timing is selected based on the *Timing Analysis* published in the Technical Resource Service of the Red River of the North.

Coincidental peak flows from the Two Rivers tributary for corresponding peak flows on the Red River of the North at Drayton, ND are derived from the USGS mean daily flow record at the Hallock gage. It is assumed that the coincident flow at Hallock occurred one day prior to the instantaneous peak at Drayton. The Hallock gage is located on the South Branch of the Two Rivers, upstream of its confluence with the Red River. **Table 33** lists the coincident flow data series.

Table 33. Two Rivers @ Hallock, WET (1942-2009) Coincidental Flow Record

Water Year	Coincidental Flow, cfs	Water Year	Coincidental Flow, cfs
1942	1,300	1976	248
1943	740	1977	113
1944	Missing	1978	1,460
1945	500	1979	1,697
1946	500	1980	572
1947	70	1981	117
1948	1,600	1982	0
1949	1,000	1983	0
1950	3,400	1984	0
1951	1,350	1985	128
1952	39	1986	845
1953	16	1987	709
1954	321	1988	233
1955	639	1989	1,573
1956	1,157	1990	61
1957	537	1991	2,169
1958	228	1992	200
1959	867	1993	2,349
1960	1,258	1994	132
1961	16	1995	403
1962	683	1996	3,294
1963	514	1997	2,619
1964	396	1998	164
1965	723	1999	3,553
1966	3,035	2000	194
1967	917	2001	1,483
1968	1,016	2002	944
1969	1,224	2003	35
1970	2,642	2004	1,088
1971	1,303	2005	900
1972	974	2006	2,045
1973	62	2007	314
1974	1,517	2008	99
1975	1,280	2009	1,005

[illegible]

The flow-frequency curve for the WET portion (1942-2009) of the period of record at Hallock is developed using the observed coincidental flows at Hallock. A graphical curve is fit to the coincident peak flow data, plotted using the Weibull plotting position. The graphical curve can be found in **Figure 30**.

The coincidental flow-frequency curve at Hallock must be transferred to the confluence of the Two Rivers with the Red River. This is done using general relations methodology. This technique uses a drainage area ratio relating the drainage area at Hallock to the drainage area associated with the confluence of the Two Rivers with the Red River. The drainage area ratio is applied to the Hallock flow frequency curve in order to generate the projected coincident flows at the confluence of the Two Rivers and Red River of the North. **Table 34** contains the values used to transfer coincidental flows from Hallock to the confluence of the Two Rivers with the Red River for the WET flow-frequency curve.

Table 34. Flow Transfer from Hallock Gage- WET Analysis (1942-2009)

Exceedance Probability	Hallock Coincidental Discharge (cfs)	Drainage Area Ratio	Coincident Flows at Confluence (cfs)
0.002	3,550	1.968	6986
0.005	3,500	1.968	6888
0.01	3,450	1.968	6790
0.02	3,400	1.968	6691
0.05	2,950	1.968	5806
0.1	2,350	1.968	4625
0.2	1600	1.968	3149
0.5	550	1.968	1082
	Hallock		Mouth
Drainage Area (sq. mi)	625		1230

4.2.3 2006 Event Hydrograph Routing

The USGS recorded 2006 spring flood hydrograph is routed from Drayton to Emerson in order to develop pattern hydrographs at ungaged locations of interest along this reach of the Red River.

The flows associated with the North Branch of the Two Rivers, as well as the local runoff between Hallock and the mouth of the Two Rivers can be estimated using a drainage area ratio and the flow record at Grafton. The drainage area ratio utilized, as well as the drainage areas used to determine this ratio, can be found in **Table 35**.

Table 35. Drainage Areas used to Determine Local Flow

Area	Total D.A (sq. miles)	Source
Two Rivers Watershed	1,230	USACE 1988 Timing Analysis
Hallock	605	USGS
Local Flow D.A	625	Computed
Grafton (ref. flow record)	695	USGS
D.A Ratio	0.871	

Because Hallock is relatively close to the confluence of the Two Rivers with the Red River of the North, the flows at Hallock can be routed directly to the confluence. The flows at Hallock are combined with the local flow record. The local flow record is lagged one day to account for travel time. From these routed flows, a coincident flow record can be developed at the confluence of Two Rivers with the Red River of the North. This coincident flow record is used to develop a coincident flow-frequency curve at this location. The 2006 spring flood event can also be determined from the routed flow record.

Based on this methodology, a flow of 60.3 cfs is produced on Dec. 12, 1991. This is reasonably close to the recorded flow value of 64.2 cfs.

4.3 Pembina River

4.3.1 Available Data & Hydrologic Properties

The headwaters of the Pembina River are located in Manitoba, Canada. The Pembina River flows southeasterly and crosses into the United States about 15 miles northwest of Walhalla, North Dakota. The confluence of the Pembina River with the Red River of North is located near Pembina, North Dakota.

4.3.1.1 Hydrology & Geomorphology

The flow characteristics associated with the Pembina River during flood events can be attributed to the region's geomorphology. Near Wahalla, the river flows upon what was formerly Lake Agassiz lakebed. Between Wahalla and Neche the river valley disapears. Downstream of Neche the riverbed is perched, meaning that the riverbed is higher than the floodplains. The terrain between Wahalla and the mouth of the Pembina River is very flat which makes the area suseptible to flooding. The Tongue River enters the Pembina River a few miles upstream of the Pembina River's confluence with the Red Rver of the North.

4.3.1.2 Available Flow Data

As can be seen in **Figure 31**, the USGS has flow gages located on the Pembina River at Walhalla, ND (USGS Gage 05099600) and at Neche, ND (USGS Gage 05100000). Both the Wahalla and Neche gages have daily flow records for the period of record between 1942 and 2009.

4.3.1.3 Breakout Flows

Water Management Consultants' *Hydrodynamic Modeling of the Lower Pembina River Report,* published for the International Joint Commission (IJC), indicates that breakout flows occur on the Pembina River upstream and downstream of Neche.

The USGS record at Neche has sporatically been adjusted to include upstream breakout flows. The IJC report indicates that only minor breakout flows occur above Neche (~ 5% of the flow).

According to model reports generated for the IJC and antedotal reports provided by area residents, major breakouts occur downstream of Neche. This was confirmed by the North Dakota State Water Commission (NDSWC). The photograph taken during the spring flood event of 2009, displayed in **Figure 32**, illustrates the magnitude of these breakout flows.

According to the NDSWC, breakout flows ocurr on the Pembina River about one mile downstream of Neche, ND. These breakout flows were historically contained by agricultural dikes. The majority of these dikes have since been removed. Flows leave the Pembina River and breakout equally north and south of the river. The NDSWC stated that the flows that breakout from the Pembina River to the south enter the London Coulee and then enter a large innundated area south of the Pembina River. The flows that breakout to the north flow to the international border and follow the border dike eastward until they re-enter the Pembina River near Pembina, ND. According to the NDSWC the majority of these flows only re-enter the system after the Red River of the North had peaked.The IJC report includes the estimated magnitudes of breakout flows downstream of Neche for the 1996 and 1997 flood events. These magnitudes are visually displayed in **Figure 33** and **Figure 34**.

According to the U.S Army Corps of Engineer's Environmental Impact Statement for Flood Control for the Pembina River, bankfull flow for the Pembina River near Neche, ND is 3,500 cfs. By adopting 3,500 cfs as the bankfull condition for the Pembina River and by using the values provided for in the IJC report, a curve can be developed relating the observed flows at Neche, ND to downstream breakout flows as can be seen in **Figure 35**.

The relationship displayed in **Figure 35** can be applied to the observed flow record at Neche to accound for breakout flows. It is assumed that by the time the breakout flows re-enter the Red River of the North/ Pembina River system they would no longer affect the magnitude of the peak on the Red and thus it is not necessary to re-route the breakout into the Pembina or Red River.

4.3.1.4 Tongue River

There is a USGS gage located on the Tongue River at Akra, ND (USGS 05101000). The flow record at Akra includes missing data points and only extends back to 1950.

4.3.2 Coincidental Flow Frequency Analysis

Coincident timing is selected based on the *Timing Analysis* published in the Technical Resource Service of the Red River of the North.

Coincidental peak flows from the Pembina River tributary for corresponding peak flows on the Red River at Emerson, ND are derived from flows at the Walhalla gage upstream of the confluence of the Pembina River with the Red River. It is assumed that the coincident peak at Walhalla occurred three days prior to the instantaneous peak at Emerson. **Table 36** lists the coincident flow data series.

Table 36. Pembina River @ Walhalla, Coincidental Flows- WET Analysis (1944-2009)

Water Year	Coincidental Flow, cfs	Water Year	Coincidental Flow, cfs
1944	2,800	1977	980
1945	386	1978	2,400
1946	320	1979	60
1947	1,560	1980	866
1948	911	1981	3,170
1949	179	1982	355
1950	2,180	1983	26
1951	3,740	1984	750
1952	4,040	1985	1,370
1953	721	1986	135
1954	221	1987	1,120
1955	199	1988	920
1956	120	1989	4,420
1957	2,400	1990	241
1958	5,080	1991	401
1959	55	1992	434
1960	16	1993	-
1961	800	1994	-
1962	1,600	1995	-
1963	200	1996	806
1964	1,880	1997	1,550
1965	170	1998	-
1966	175	1999	-
1967	565	2000	-
1968	1,190	2001	-
1969	550	2002	49
1970	39	2003	4,490
1971	6,570	2004	906
1972	4,120	2005	64
1973	7,160	2006	3,700
1974	1,780	2007	4,270
1975	155	2008	6,580
1976	5,540	2009	1,600

[illegible]

The flow-frequency curve for the WET portion (1942-2009) of the flow record at Walhalla is developed using the observed coincident flows. A graphical curve is fit to the coincident peak flow data plotted using the Weibull plotting position. The graphical curve can be found in **Figure 36.**

The frequency curve at Walhalla has to be transferred to the confluence of the Pembina River with the Red River. This is done using general relations methodology. This technique uses a drainage area ratio relating the drainage area at Walhalla to the drainage area associated with the confluence of the Pembina River with the Red River. The drainage area ratio is applied to the Walhalla flow frequency curve in order to generate the projected coincident flows at the confluence of the Pembina River and Red River of the North. **Table 37** contains the values used to transfer coincidental flows from Walhalla to the confluence of the Pembina River with the Red River for the WET flow-frequency curve.

Table 37. Flow Transfer from Walhalla to the Confluence of the Pembina River with the Red.

% Chance Exceedance	Walhalla Peak Discharge (cfs)	Drainage Area Ratio	Coincident Flows at Confluence (cfs)
0.002	7,900	1.19	9427
0.005	7,800	1.19	9308
0.01	7,700	1.19	9189
0.02	7,400	1.19	8831
0.05	6,200	1.19	7399
0.1	4,800	1.19	5728
0.2	3050	1.19	3640
0.5	840	1.19	1002
	Walhalla		Mouth
Drainage Area (sq mi)	3310		3950

4.3.3 2006 Event Hydrograph Routing

The USGS recorded 2006 spring flood hydrograph is routed from Drayton to Emerson in order to develop pattern hydrographs at ungaged locations of interest along this reach of the Red River.

Observed flows at Neche are routed through the breakout flow transform and then downstream using Straddle Stagger routing parameters. Parameters are based on the U.S Army Corps of Engineers *1988 Timing Analysis*. The daily flow record at Akra is routed to the mouth of the Pembina River using Straddle Stagger routing parameters based on the U.S Army Corps of Engineers 1988 *Timing Analysis*.

The flows associated with the Pembina River and Tongue River are combined and added to an estimate of the local area runoff associated with the drainage area between Neche and the mouth of the Pembina River (exculding the Tongue River drainage area). Local flow are determined using a drainage area ratio and the observed flow record at Neche. The drainage area ratio utilized, as well as the drainage areas used to determine this ratio, can be found in **Table 38**.

Table 38. Drainage Areas used to develop local flows for Pembina River

Local Area	Total D.A (sq. miles)	Source
Pembina River	3,950	Timing Analysis
Neche	3,410	USGS
Local Area Neche to Mouth (WO Tongue R)	380	Calculated
Akra (Tongue R)	160	USGS
Reference Gage	**Ratio**	
Neche	0.11	

The resulting flow record at the confluence of the Pembina River with the Red River of the North is used to develop a coincident annual peak flow record at the mouth of the Pembina River, as well as to develop the 2006 hydrograph at this location. The coincident peak flow record can be used to develop a coincidental peak flow-frequency curve representative of the confluence of the Pembina River with the Red River of the North.

4.4 BALANCED HYDROGRAPHS BETWEEN DRAYTON & EMERSON

The St. Paul District Corps of Engineers developed balanced hydrographs at all pertinent computation points located on the reach of the Red River of the North between Drayton, ND and Emerson, Manitoba, Canada in support of the unsteady RAS model. Hydrographs were generated for the 0.2-, 0.5-, 1-, 2-, and 10-percent exceedance frequency events for the WET portion of the period of record.

Coincidental balanced hydrographs are required for the confluences of the Two Rivers and Pembina River with the Red River of the North. Balanced hydrographs on the main stem of the Red River of the North are required upstream and downstream of each of the tributaries.

4.4.1. Volume Duration Analysis

In order to develop balanced hydrographs for ungaged points of interest upstream and downstream of the tributaries along the mainstem of the Red River between Drayton and Emerson, it is necessary to develop volume duration curves at these locations. Volume duration curves cannot be generated directly because no mean daily flow record exists at ungaged sites. In order to develop these curves, a volume duration curve generated for the gaged locations at Drayton and Emerson are used to determine the proportional change in volume between the 1-day duration (flow frequency values) and the other durations of interest. This proportional change in volume is applied to the adopted flow-frequency curves at the ungaged locations in order to generate the volume duration curves.

Volume duration curves also must be developed at the confluences of the tributaries with the Red River. Because volume duration curves cannot be directly developed for coincidental flows, the volume duration curves at these locations are generated by using volume duration curves generated from gaged locations along the tributaries. The volume duration curves at these gaged locations are used to determine the proportional change in volume between the 1-day duration and other durations of interest. This proportional change in volume is then applied to the adopted flow-frequency curves for the mouths of the tributaries in order to generate the volume duration curves.

The points of interest along the Red River reach between Drayton and Emerson, along with the hydraulically similar site used to generate the volume duration curves, are listed in **Table 39**.

Table 39. Reference Gages

Location	River	Volume Type	Hydrologically Similar Location used for generating Flood Volume Frequency Curve or alternate method used to obtain Balanced hydrograph
Drayton	Red River	Mainstem	Drayton
Red River US of Two Rivers	Red River	Main Stem	Drayton
Two Rivers at Mouth	Two Rivers	Coincidental	Hallock
Red River DS of Two Rivers	Red River	Main Stem	Drayton
Red River US of Pembina	Red River	Main Stem	Emerson
Pembina at Mouth	Pembina River	Coincidental	Walhalla
Emerson	Red River	Mainstem	Emerson

4.2 Balanced Hydrographs

The Hydrologic Engineering Center's Flood Hydrograph Package, HEC-1 is used to configure balanced hydrographs. To configure these balanced hydrographs, flood volume duration frequency analysis provides for the volume at each duration and specified frequency. HEC-1 also requires a pattern event. For the Fargo-Moorhead Metro Feasibility Study, the 2006 Spring Flood Event is the pattern event. The pattern event helps establish the shape and timing of the hydrograph.

5. References

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14. "05079000 Red Lake River at Crookston, MN". Water Data Report 2009. USGS.
15. "Technical Resource Service Red River of the North, Volume I: Timing Analysis," St. Paul District, US Army Corps of Engineers, March 1988.

FIGURES

Figure 1- Flow Chart for the Red River of the North between Halstad and Grand Forks

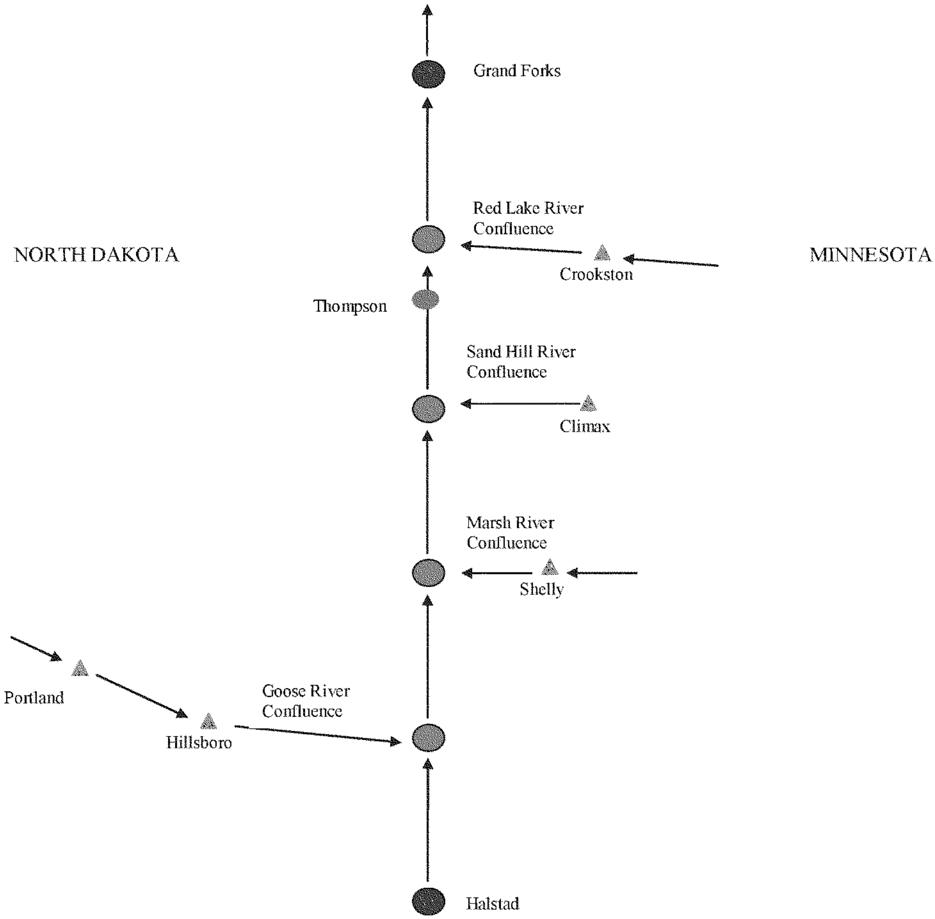
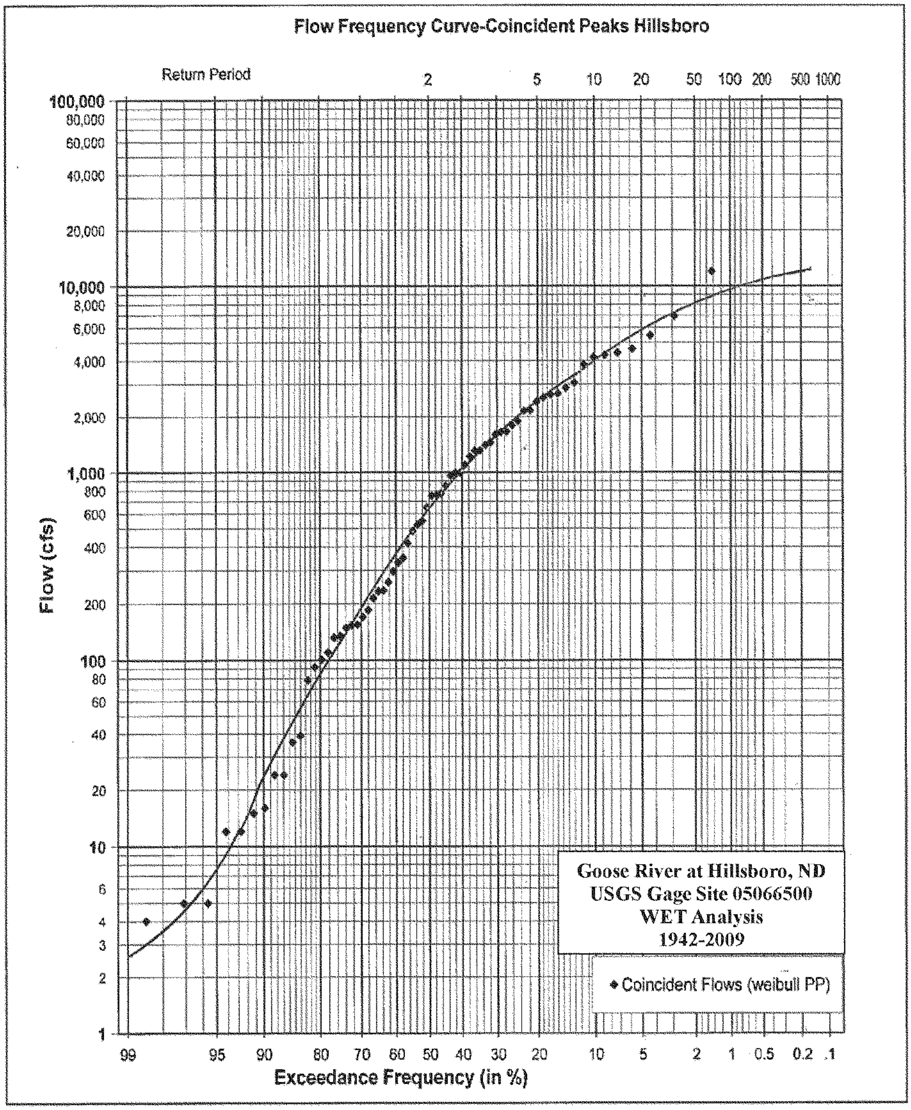
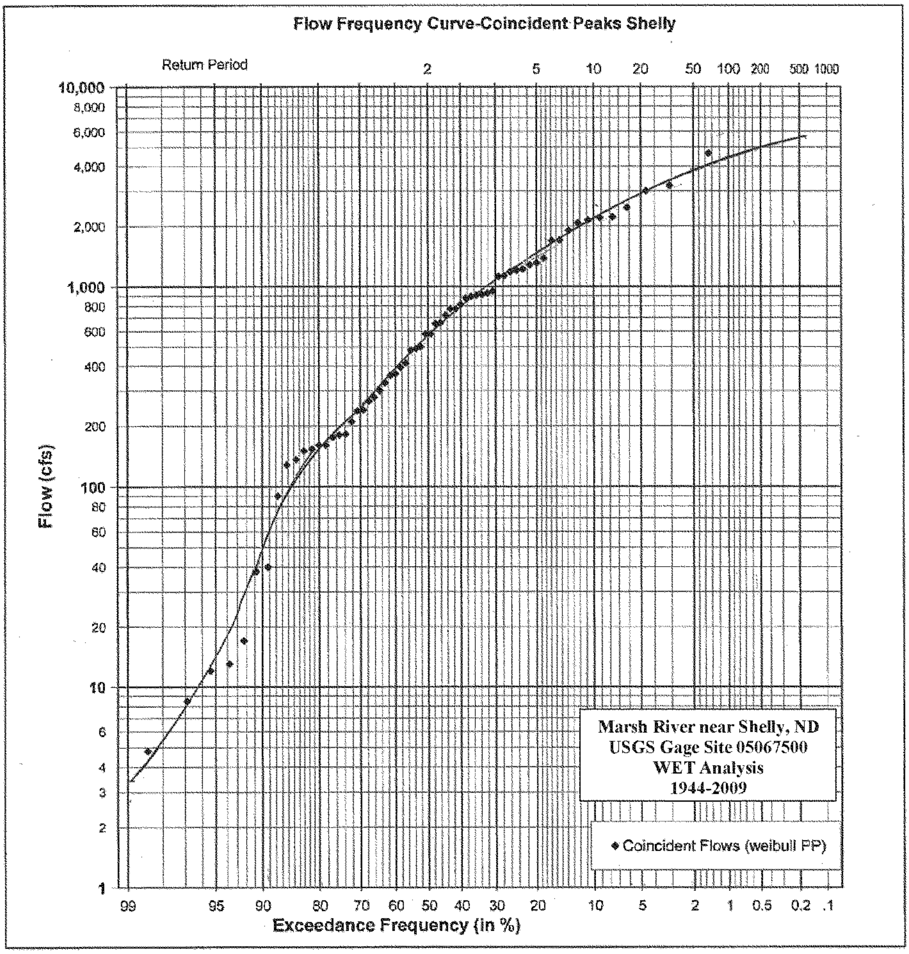


Figure 2- Graphical Coincident Flow-Frequency Curve at Hillsboro, ND



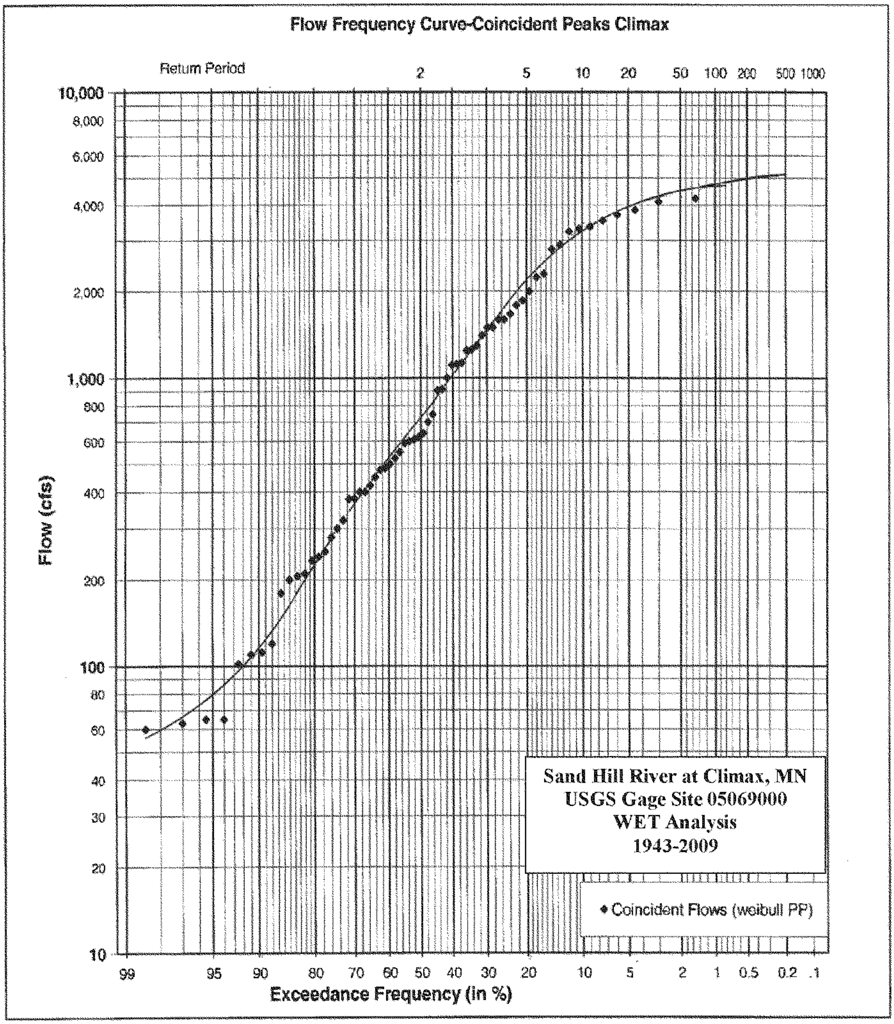
Pencil Line = Graphical Flow Frequency Curve

Figure 3- Graphical Coincident Flow-Frequency Curve at Shelly, MN



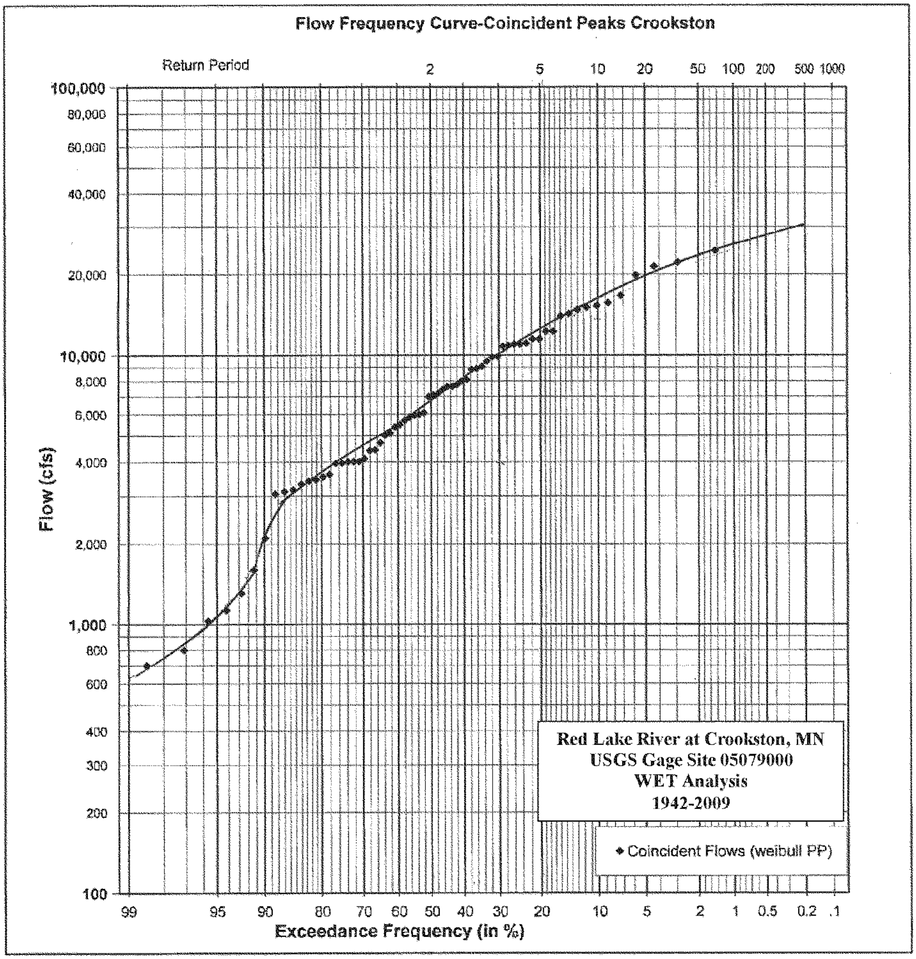
Pencil Line = Graphical Flow Frequency Curve

Figure 4- Graphical Coincident Flow-Frequency Curve at Climax, MN



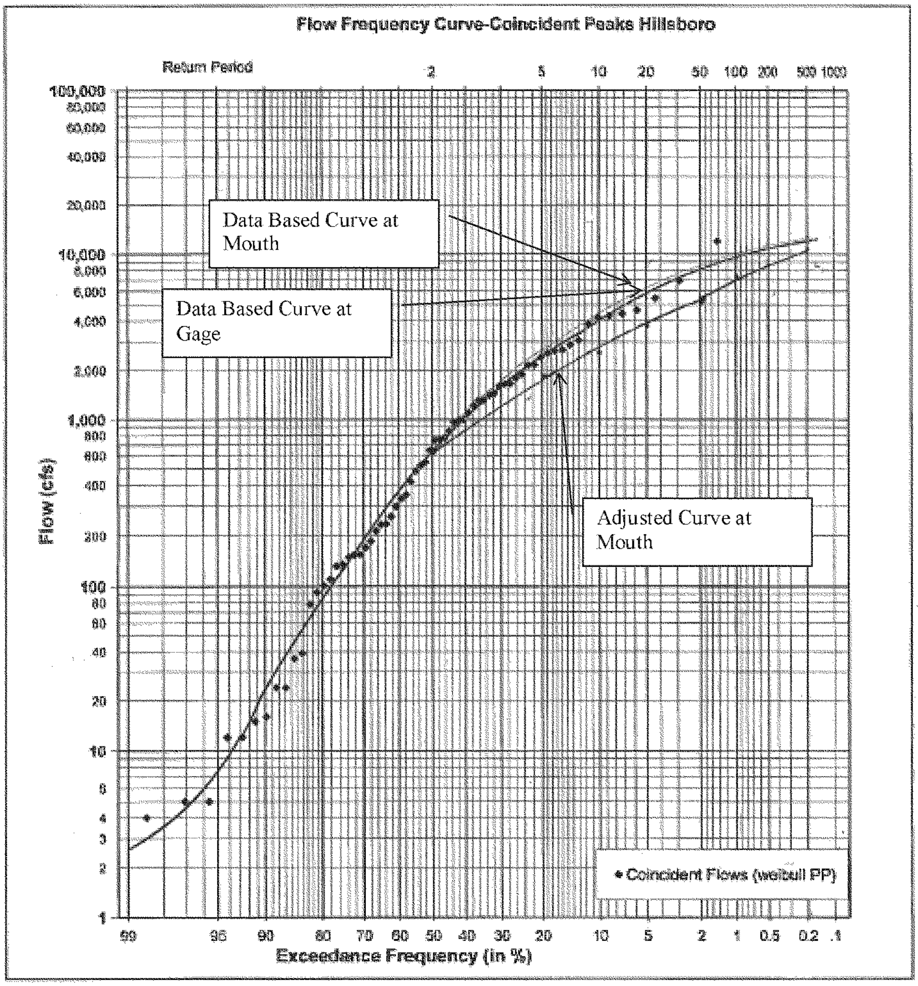
Pencil Line = Graphical Flow Frequency Curve

Figure 5- Graphical Coincident Flow-Frequency Curve at Crookston, MN



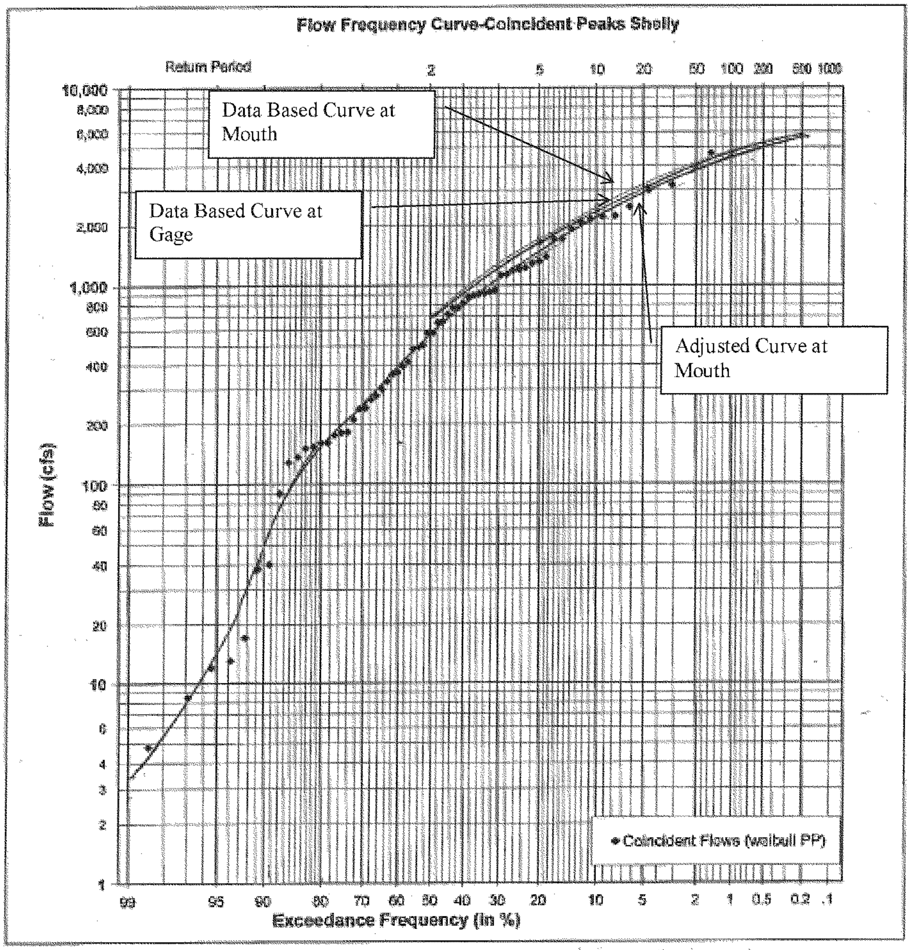
Pencil Line = Graphical Flow Frequency Curve

Figure 6. Adjusted Flow Frequency Curve- Mouth of Goose River- WET Analysis (1942-2009)



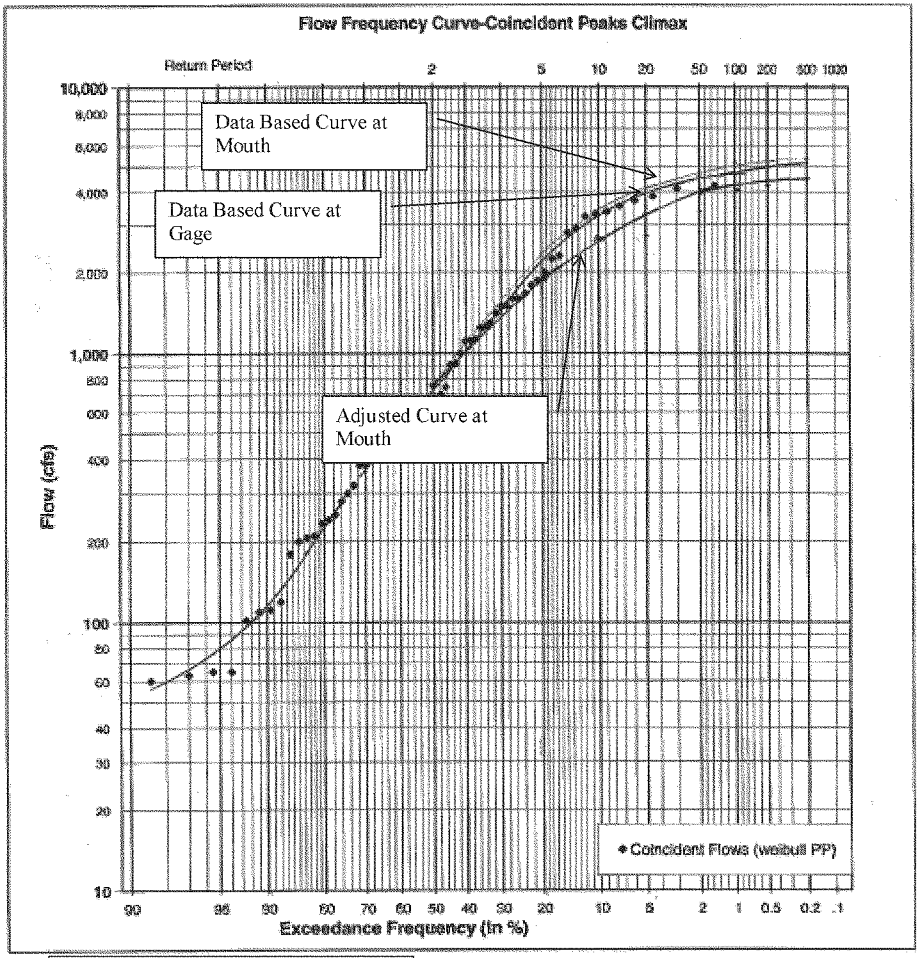
Pencil Line = Graphical Flow Frequency Curve

Figure 7. Adjusted Flow Frequency Curve- Mouth Marsh River- WET Analysis (1944-2009)



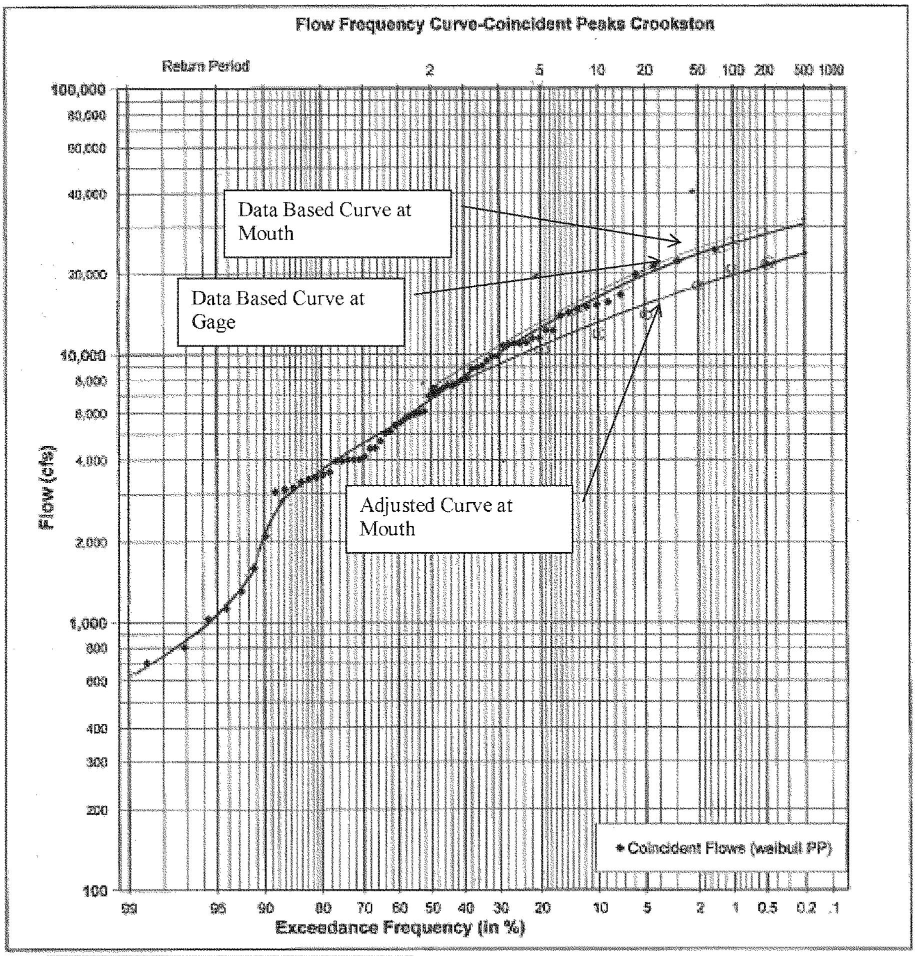
Pencil Line = Graphical Flow Frequency Curve

Figure 8-Adjusted Flow Frequency Curve- Mouth Sand Hill River Wet Analysis (1944-2009)



Pencil Line = Graphical Flow Frequency Curve

Figure 9. Adjusted Flow Frequency Curve- Mouth Red Lake River Wet Analysis (1942-2009)



Pencil Line = Graphical Flow Frequency Curve

Figure 10. Comparison between Observed and Routed Flow at Thompson, MN

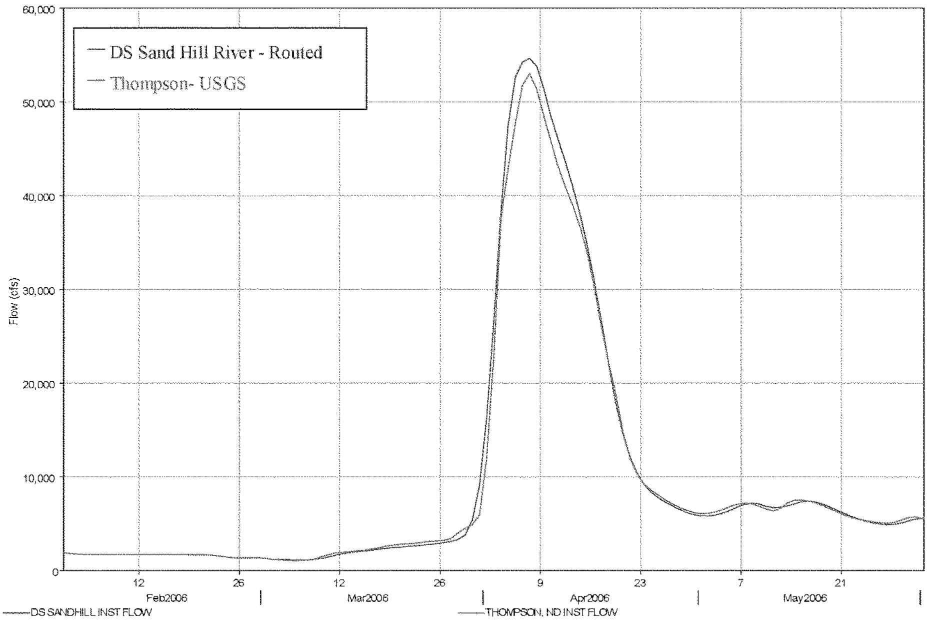


Figure 11. Comparison of Gaged based flow between Grand Forks and Thompson

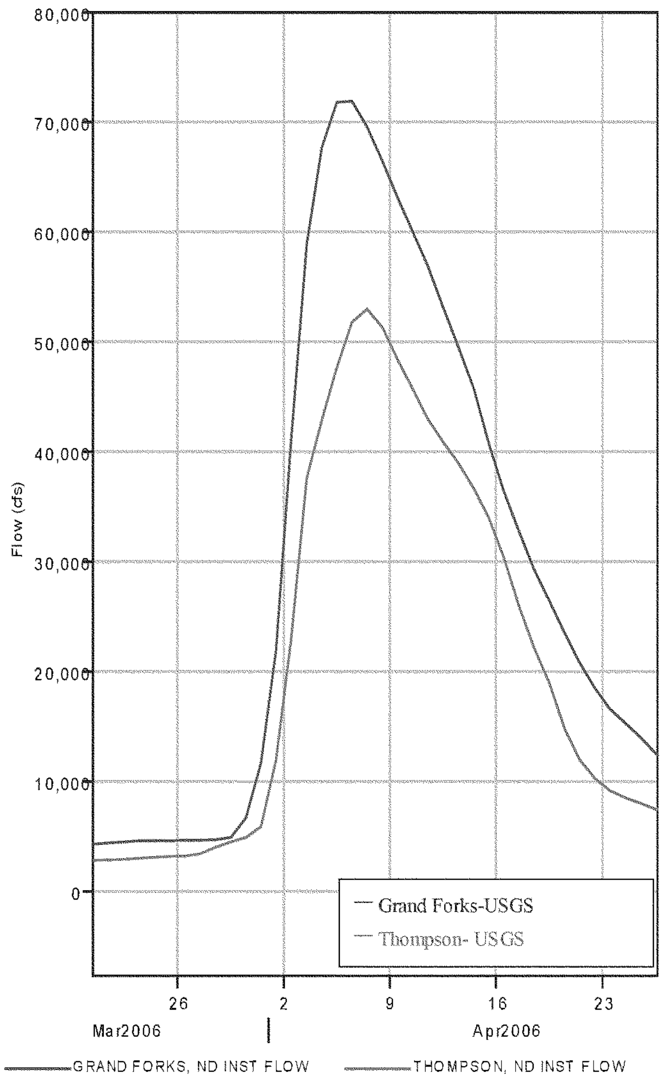


Figure 12. Routed Hydrograph and USGS gaged Hydrograph at Grand Forks

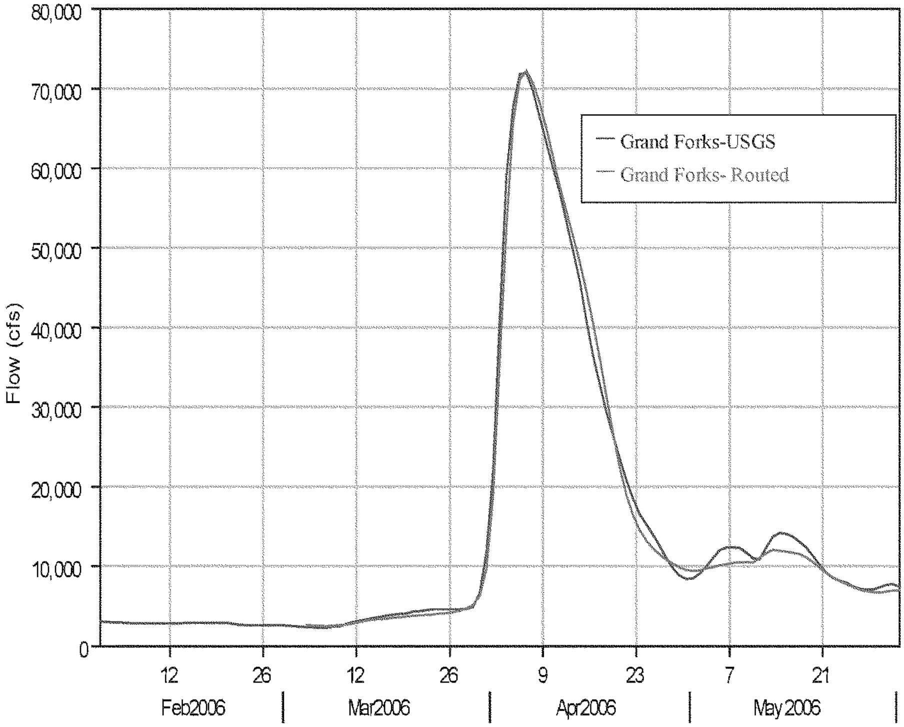


Figure 13. Timing Comparison between Routed Flows US Red Lake River and observed flows at Thompson

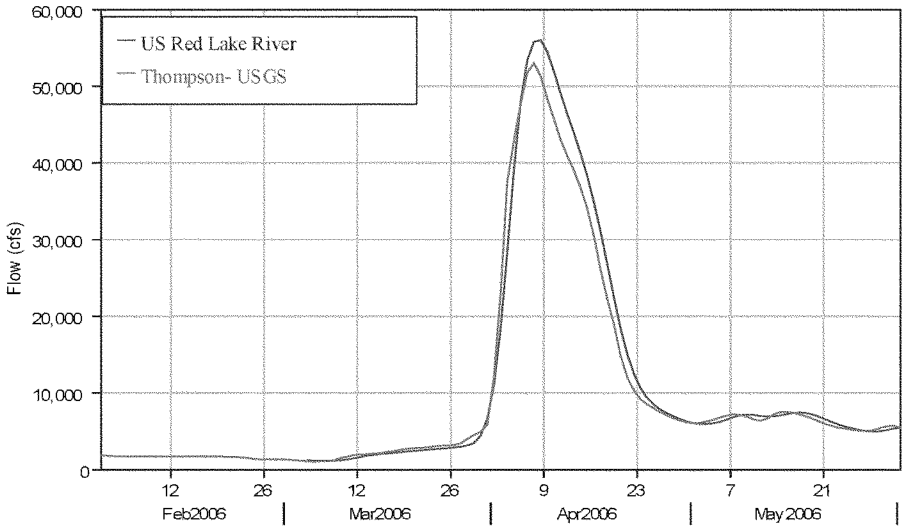


Figure 14. Adjusted Standard Deviation

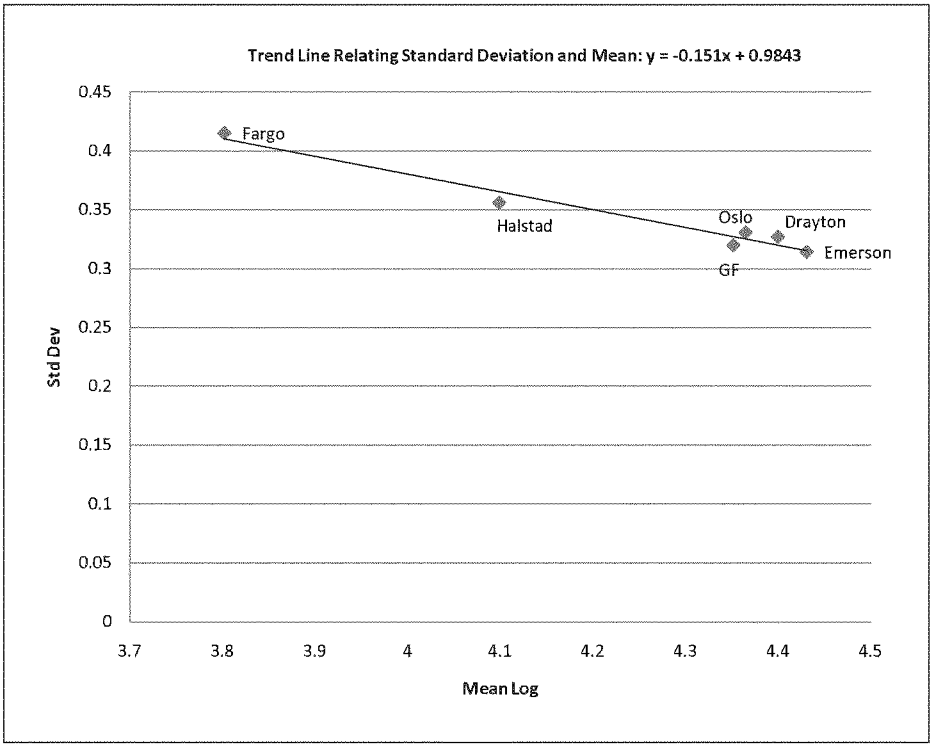


Figure 15. Adjusted Skew

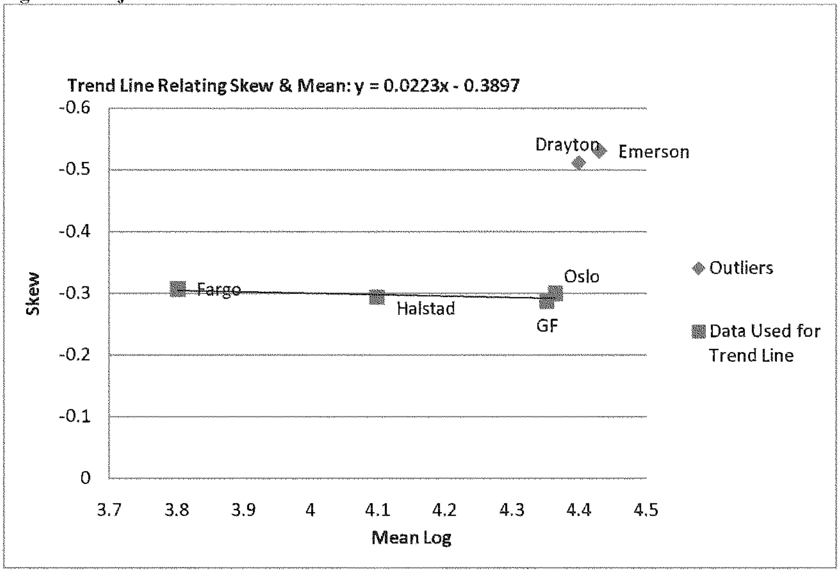


Figure 16. Nested Family of Curves on the Mainstem of the Red River of the North- WET Analysis

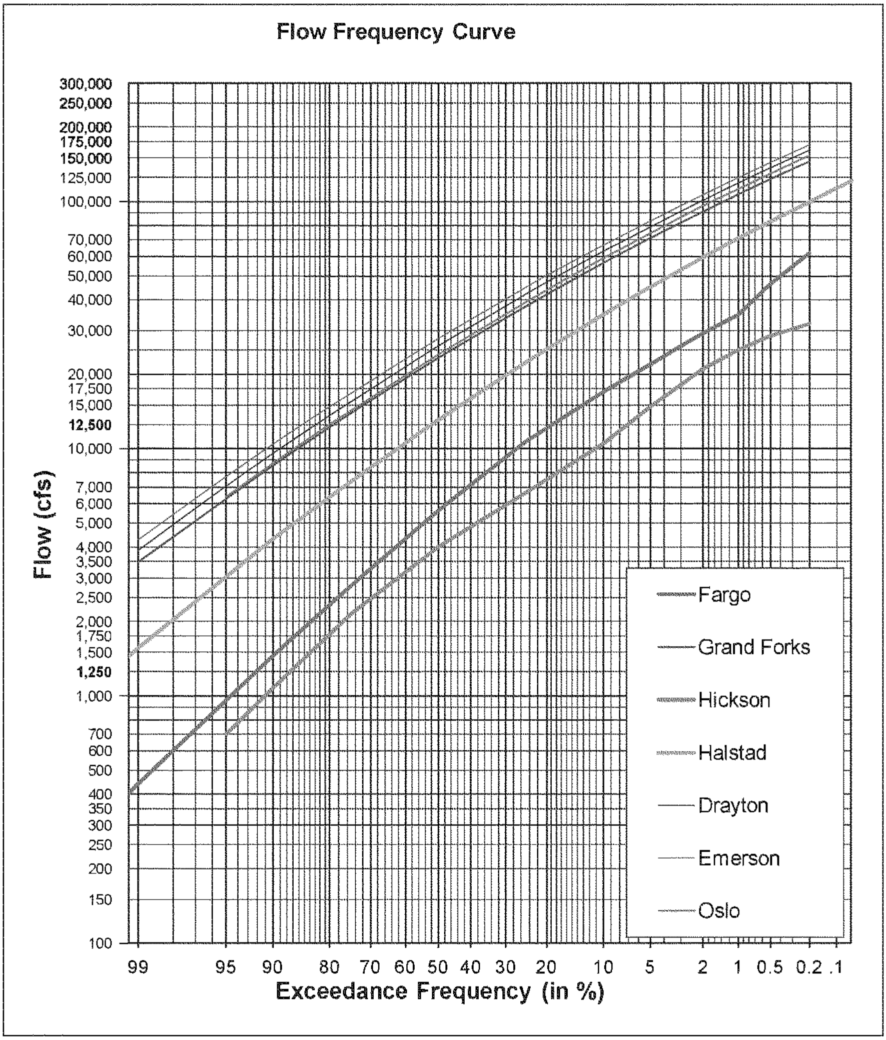


Figure 17. Schematic of Red River Reach- Grand Forks to Emerson

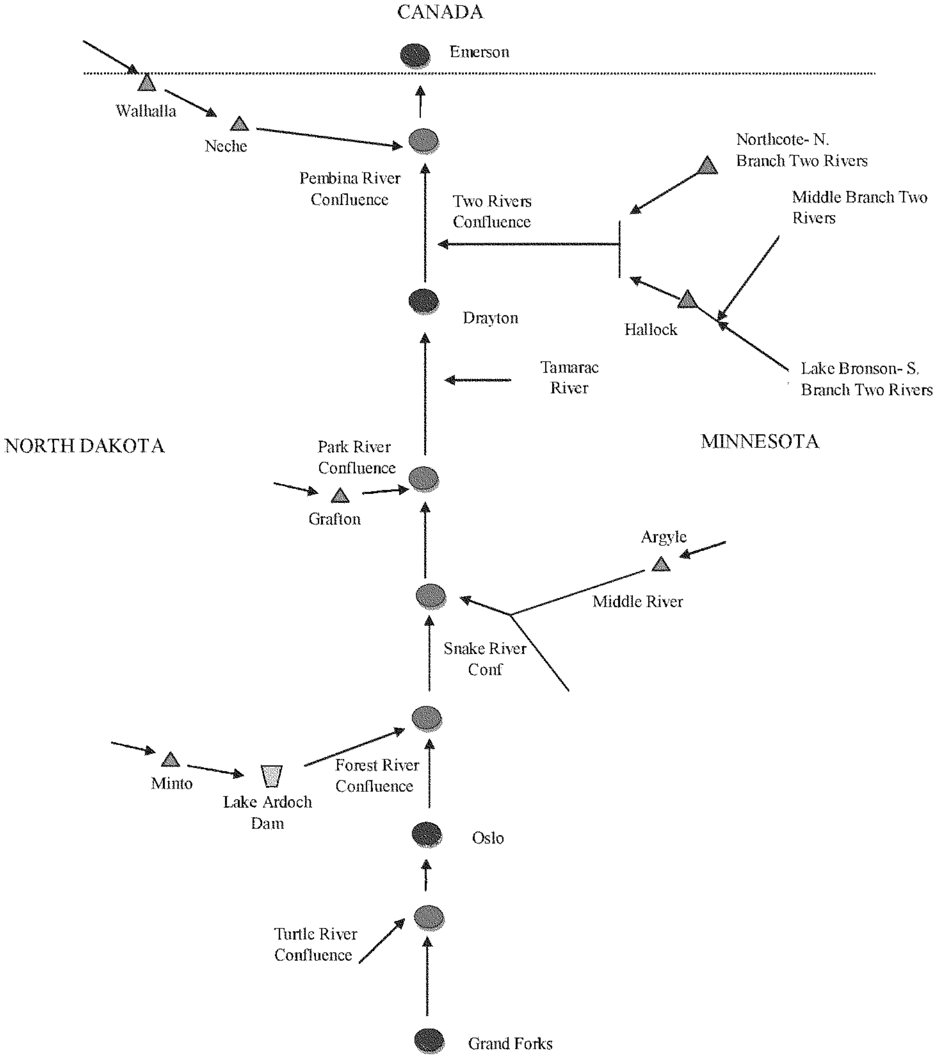


Figure 18. Red River of the North at Oslo, MN- 2006 event hydrograph- Stage

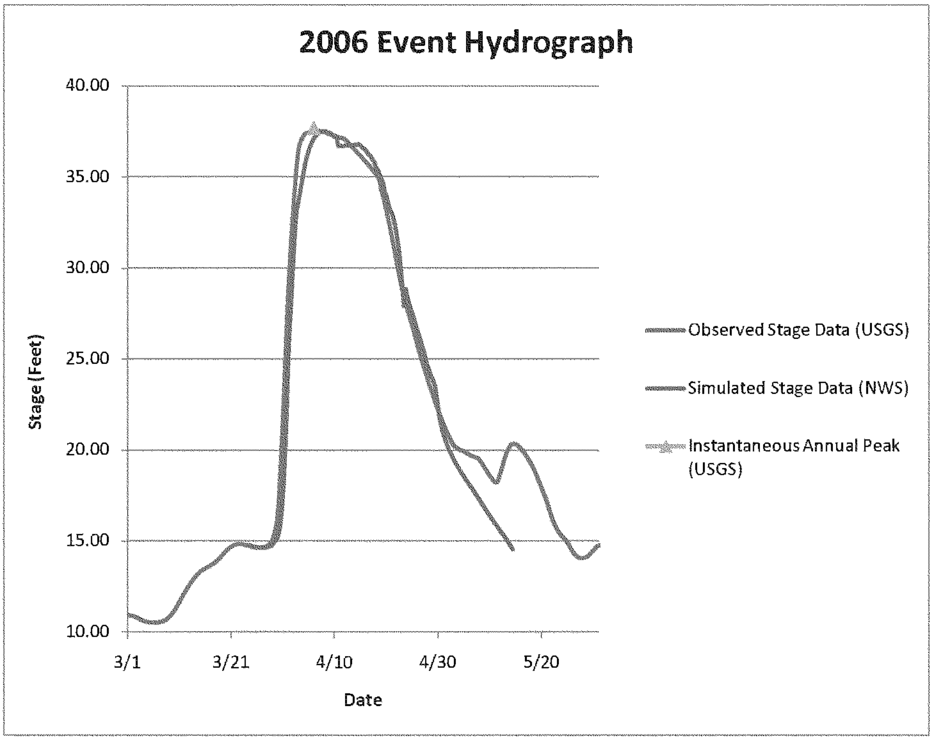


Figure 19. Red River of the North at Oslo, MN-2006 Event Hydrograph- Discharge

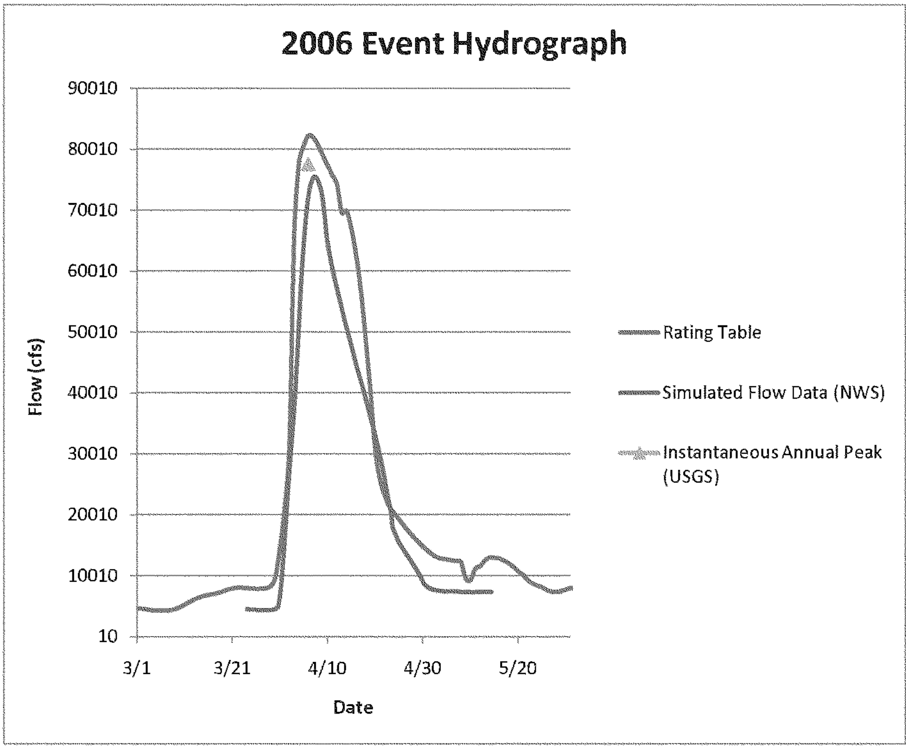


Figure 20. Available USGS Gage Data Red River Reach: Oslo- Drayton

	No Data Available
	Data Recorded

	RRN USGS GAGING STATION INFORMATION AVAILABLE FOR ANNUAL PEAKS FROM OSLO TO Drayton					
	Forest River at Minto, ND	**Forest River at Fordville, ND**	**Park River at Grafton, ND**	**Snake River at Alvarado, MN**	**Middle River/ Snake River Argyle, MN**	**Snake River Warren, MN**
Station ID	5084500/ 5085000	5084000	5090000	5085900/5 086000	5087500	5085450
START YEAR			1897			
...						
1910						
1911						
1912						
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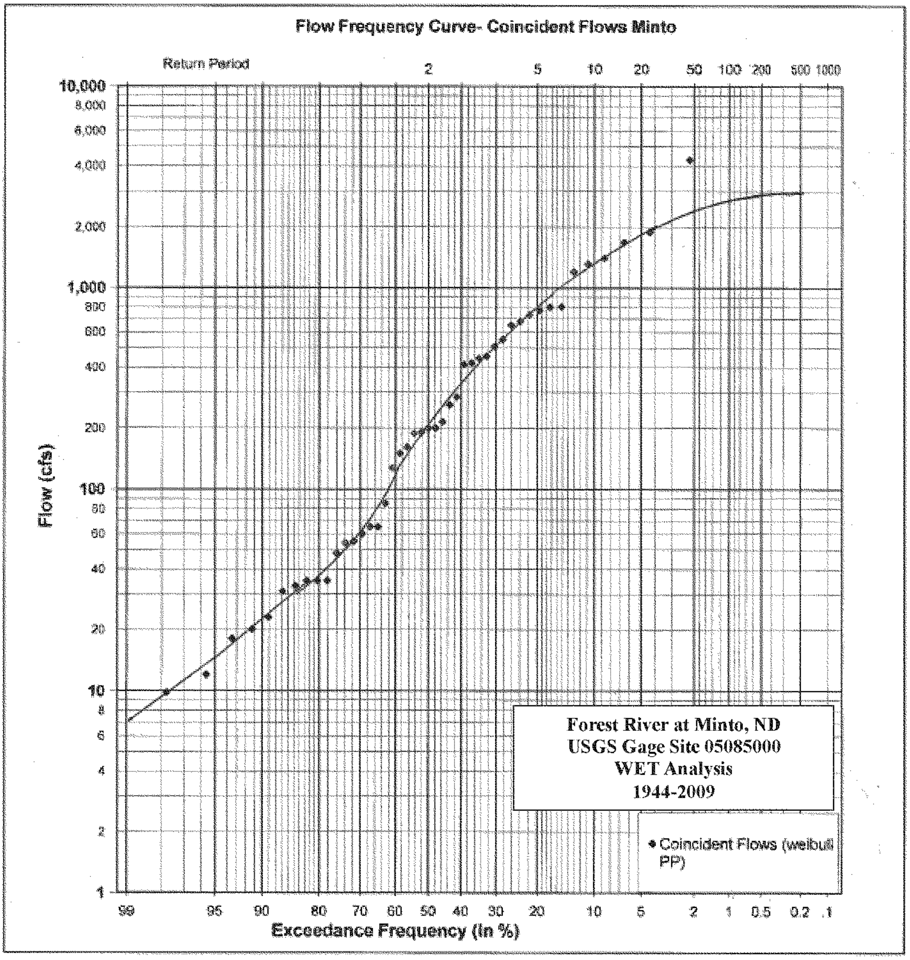
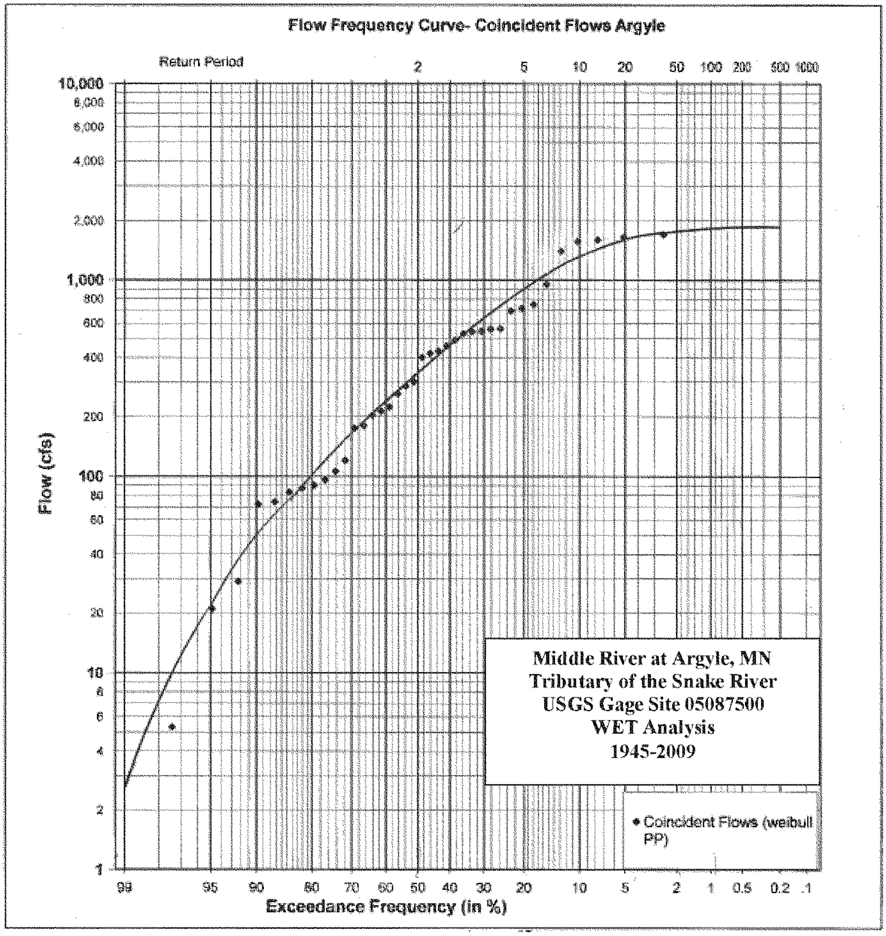
Figure 21. Coincidental Peak Flow-Frequency Curve- Forest River



Pencil Line = Graphical Flow Frequency Curve

Figure 22. Coincidental Peak Flow Frequency Curve-Argyle



Pencil Line = Graphical Flow Frequency Curve

Figure 23. Flow Drainage Area Relationship

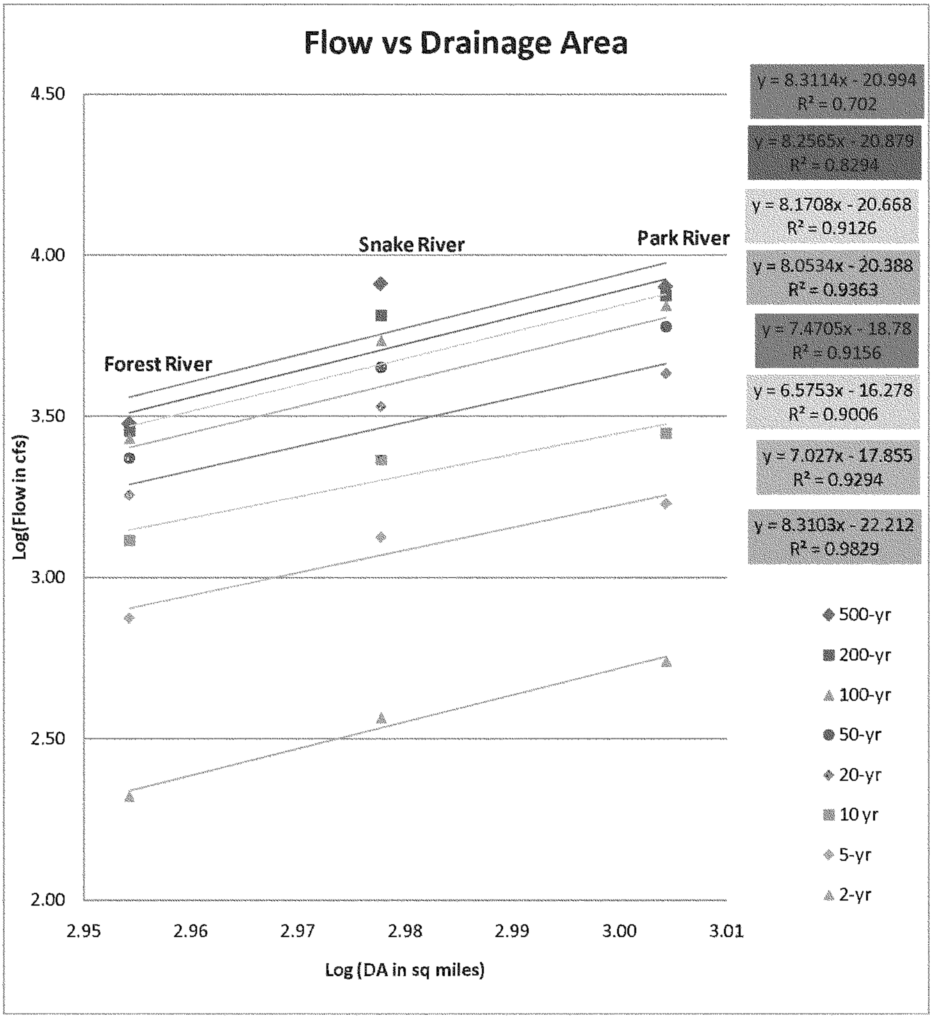
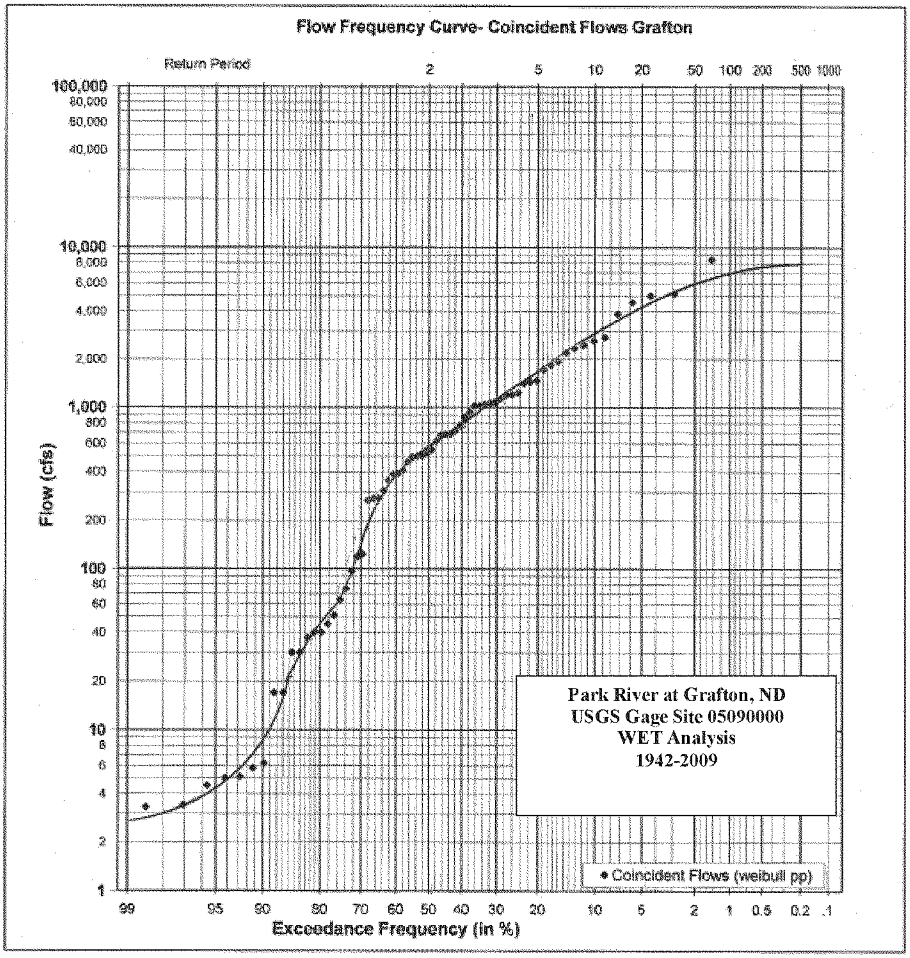
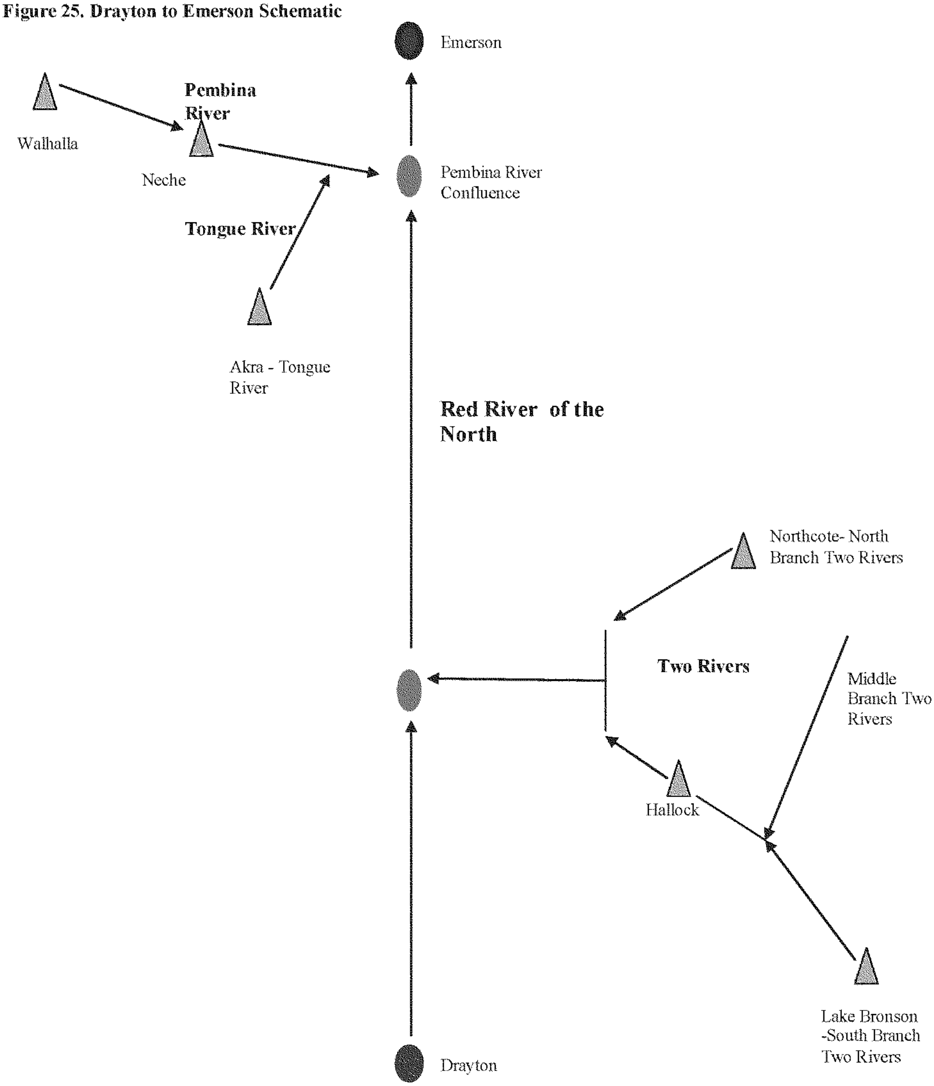


Figure 24. Coincidental Flow-Frequency Analysis at Grafton



Pencil Line = Graphical Flow Frequency Curve

Figure 25. Drayton to Emerson Schematic



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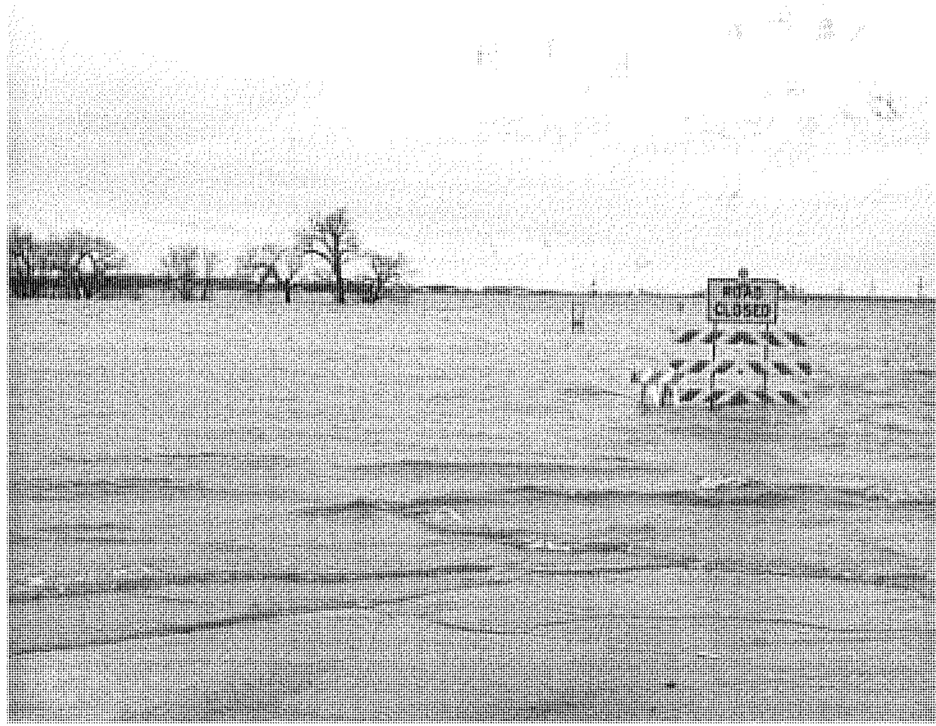

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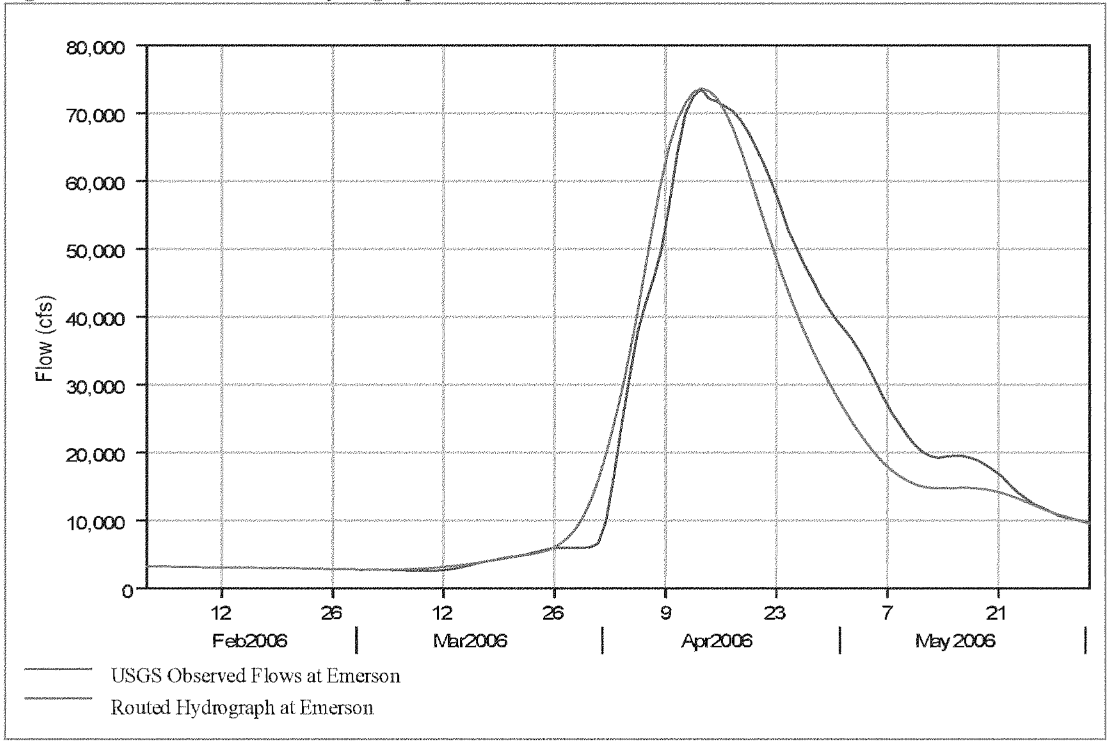


Figure 28. Two Rivers Watershed (Google Earth)

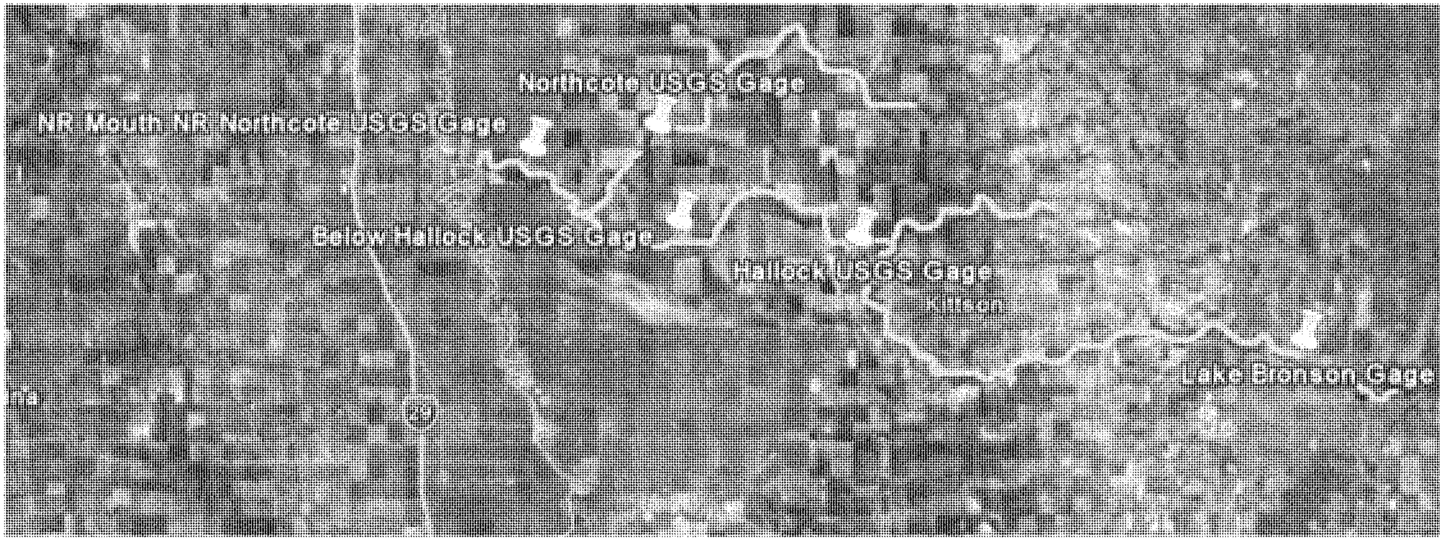


Figure 29. Linear Relationship between USGS gage at Lake Bronson and USGS gage at Hallock

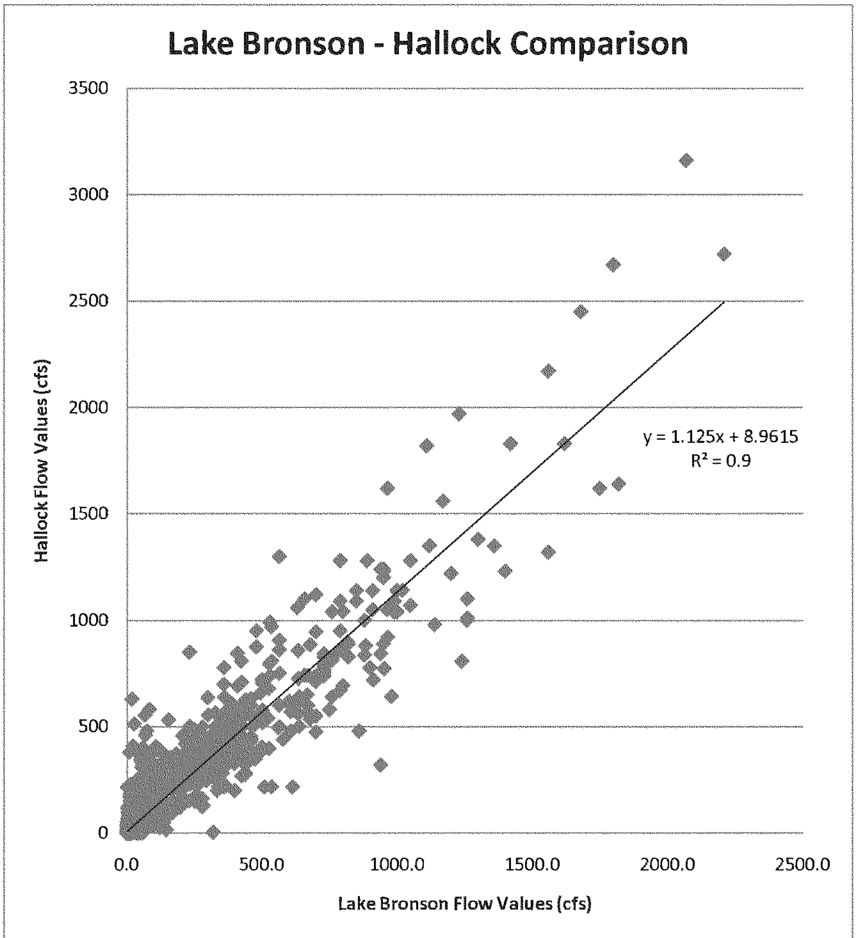
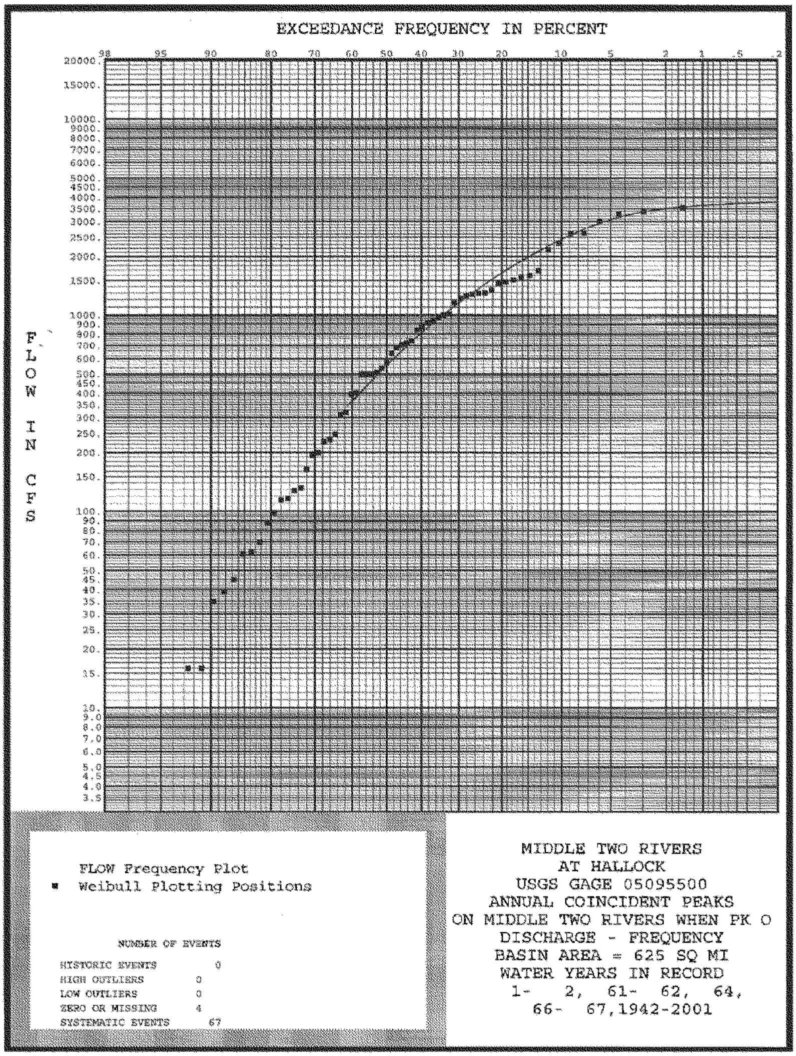


Figure 30. Two Rivers at Hallock



Pencil Line = Graphical Flow Frequency Curve

Figure 31. Pembina River

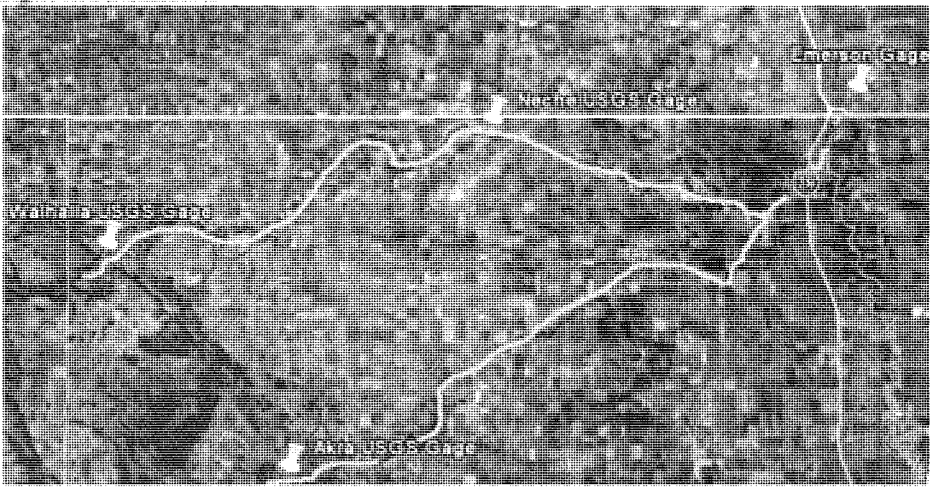


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Figure 33. 1997 Peak Flow Distribution for Existing Conditions, Peak Flow 15, 100 cfs (Water Management Consultants).

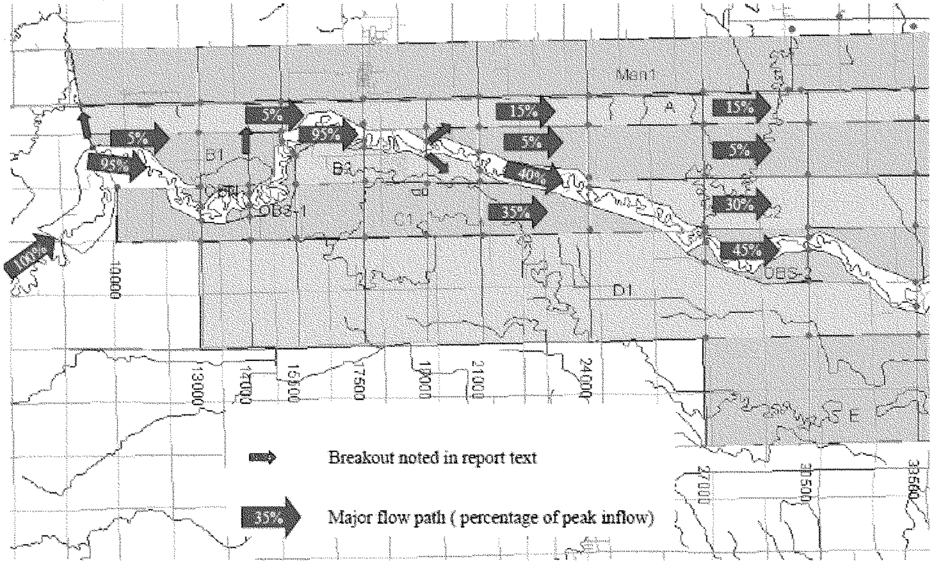
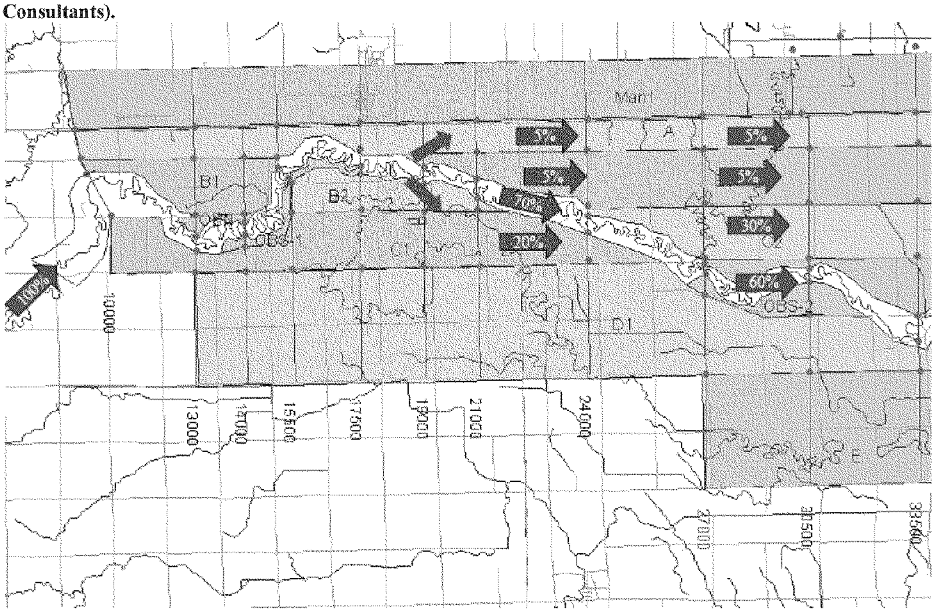


Figure 34. 1996 Peak Flow Distribution for Existing Conditions Peak Flow: 8, 500 cfs (Water Management Consultants).



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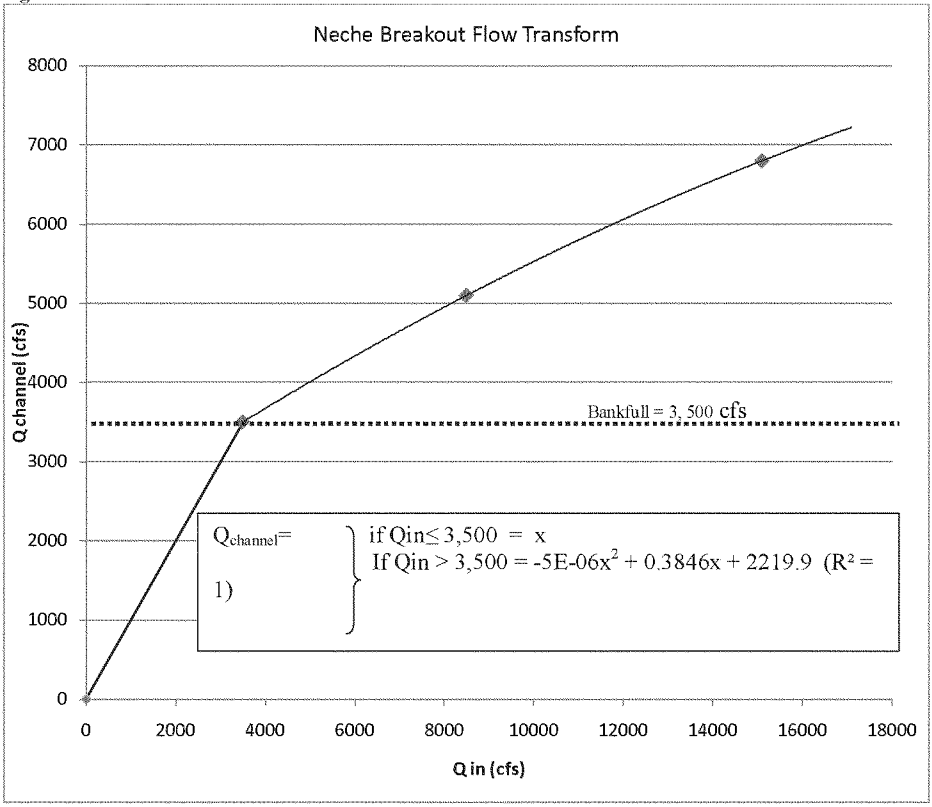

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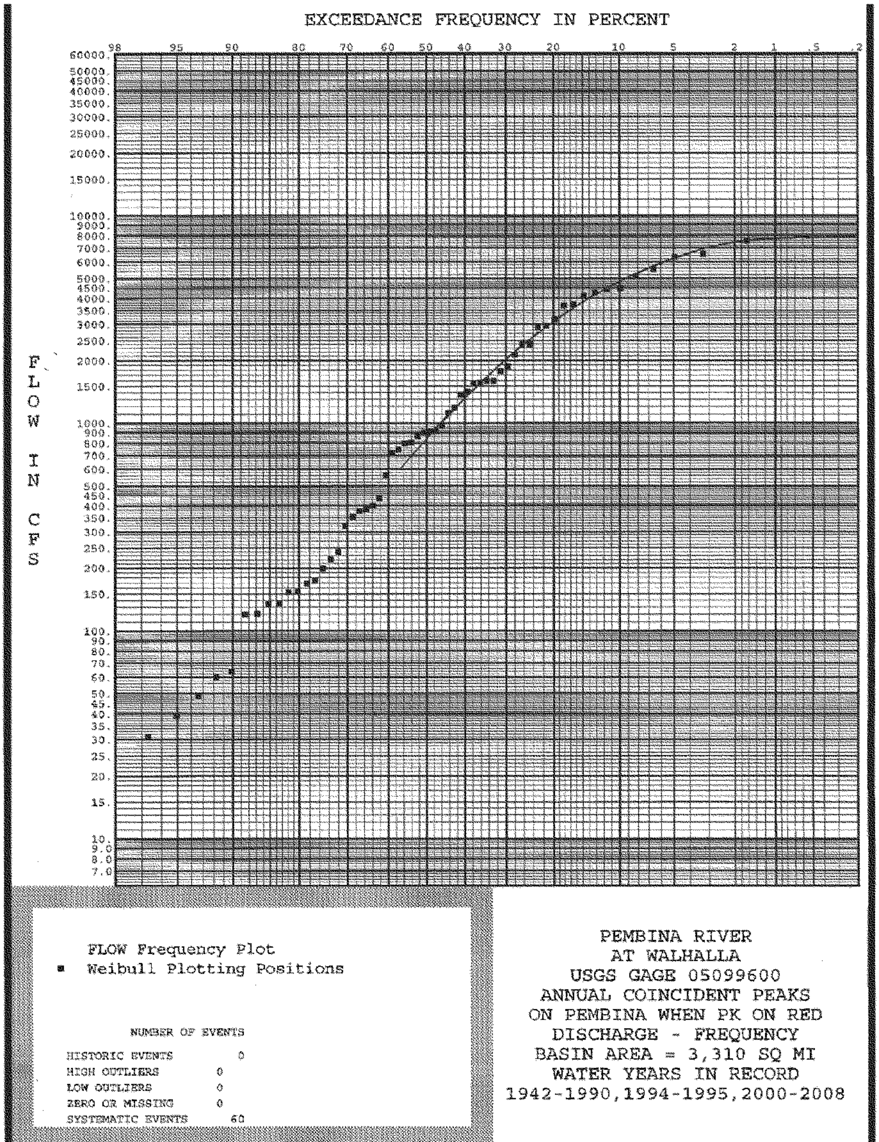

Pencil Line = Graphical Flow Frequency Curve

Appendix A-4a
Hydrology

Fargo-Moorhead Metropolitan Area Flood Risk Management

Supplemental Draft Feasibility Report and Environmental Impact Statement

April 2011

US Army Corps of Engineers ®

Prepared by:
U.S. Army Corps of Engineers
St. Paul District
180 Fifth Street East, Suite 700
St. Paul, Minnesota 55101-1678

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Preface

Following the submittal of Hydrology Appendix A-2 it was noted that the revised hydrology significantly increased flows through Fargo, ND, yet flows further downstream, at locations such as Halstad and Grand Forks flows did not increase significantly . In order to address this discrepancy it was necessary to further analyze the Red River Reach between Fargo, ND and Halstad, MN. The Lower Sheyenne River is a major tributary that reaches its confluence with the Red River just downstream of Fargo, ND. Refinement of the hydrology associated with this reach, particularly with the flows associated with the Sheyenne River resulted in more realistic output from hydraulic modeling.

Hydrological analysis is necessary to produce balanced hydrographs associated with the 0.2-, 0.5-, 1-, 2-, 3-, 4-, and 5-% exceedance frequency events in the Red River Basin. These balanced hydrographs are utilized as inputs to hydraulic modeling. In order to develop balanced hydrographs at points of interest within the Red River Basin located between Fargo, ND and Halstad, MN the 2006 event hydrograph had to be determined at all points of interest in the basin. The 2006 event hydrograph is utilized as the pattern event for balanced hydrographs. The pattern hydrograph provides for the shape and timing of the balanced hydrographs. Because not all points of interest are gaged locations, 2006 flows had to be routed throughout the basin. Routing was determined using HEC-HMS. Routing had to be determined for the Sheyenne River and its tributaries and then routed to the Sheyenne River's confluence with the Red River of the North. Flows from Fargo, ND had to be routed along the mainstem of the Red River to Halstad, MN and combined with tributary flow from the Sheyenne River, Buffalo River, Elm River and the Wild Rice River (MN). Routing was verified by calibrating to USGS streamflow gages.

1. SHEYENNE RIVER HMS MODELING

The Sheyenne River is a major tributary of the Red River of the North. It reaches its confluence with the Red River about 20 miles north of Fargo, ND. There are two major tributaries to the Sheyenne River between Baldhill Dam and its confluence with the Red River of the North: the Maple River and the Rush River. The Sheyenne River is regulated by Baldhill Dam. Baldhill Dam forms the impoundment of Lake Ashtabula and provides flood control to the downstream communities of Valley City, Lisbon and Kindred. Additional flood control measures constructed in the Lower Sheyenne River Basin include the West Fargo Diversion, the Horace Diversion and the Maple River Dam. A diagram detailing the study reach can be found in **Figure 1. Figure 5** displays available gaged data in the Lower Sheyenne River Basin.

1.1 Baldhill Dam Modeling

In a previous study that was completed in Fall 2010, Ford Consulting Engineering developed a HEC-ResSim model for Baldhill Dam and a portion of the Sheyenne River. The modeling conducted by Ford Consulting was part of a Corps Water Management System (CWMS) implementation. This ResSIM model includes the 5' pool raise at Baldhill Dam, which was implemented in 2004 and is thus representative of current regulatory conditions.

The ResSim model has control points representative of the inflows and outflows from Baldhill Dam, as well as a series of junctions located near Valley City, Lisbon, Gol Bridge and Kindred, North Dakota. The ResSIM reservoir network is displayed in **Figure 2**. Ford used Muskingum-Cunge, 8-point cross section routing throughout their model. They chose to use Muskingum-Cunge routing instead of Modified Puls routing because of the relatively flat energy gradient that exists in the Sheyenne River Basin.

The ResSIM model doesn't include the effects of the breakout flows known to occur near Kindred, ND. Because the model doesn't include the effects of breakouts, ResSim will only be used for the reach of the Sheyenne River between Baldhill Dam and Lisbon.

1.1.1 Changes made to the Ford HEC-ResSim Model

The ResSim model developed by Ford Consulting was designed to model specific events. It was not designed to be used as a continuous simulation model. The following changes to the model are necessary for continuous simulation:

1. Pool evaporation must be removed from the model. The inflow record available for modeling includes evaporation.
2. In order to more closely simulate actual operation of the reservoir the maximum outflow from the reservoir is adjusted to 6, 590 cfs. This is the maximum outflow that has historically (Spring 2009) been released from the reservoir.
3. The minimum release rule is changed to reflect the minimum release rule prescribed by the Normal Pool Drawdown Schedule which can be found in Table 7-9 of the Baldhill

Dam Water Control Manual. The minimum release rule is altered to reflect a gradual drawdown by using seasonal variation as displayed in **Table 1** :

Table 1. Minimum Release Rule

	Minimum release (cfs)			
Flow (cfs)	Jan	Feb-Mar	Apr-Sep	Oct-Dec
0	60	55	10	65
100	160	155	10	165
1, 000	1060	1055	10	1065

4. Because the Ford model was setup in order to be a regulatory aid different rule sets governing the top elevation of the conservation pool were developed that could be used given four different Snow Water Equivalent (SWE) scenarios in the basin. Different rule sets were developed for SWE <1, 1-1.5, 1.5-2 and > 2 inches.

   If a complete SWE record was available for the period of record (1942-2009) near Baldhill Dam these different scenarios could have been incorporated into the continuous simulation. Unfortunately, a complete record of SWE in the basin is not available. SWE data at Baldhill Dam is only available from the U.S Army Corps of Engineers-St. Paul District Water Control Website for the years between 1985- 2009.

   As can be seen from **Figure 3**, the majority of years for the period of record have snow water equivalent values above 2 inches (20 out of 25 years). Based on the observed SWE values and because we are most interested in capturing the larger events we selected the conservation pool elevation based on a SWE of greater than 2 inches for our continuous simulation.

<u>1.1.2 Reservoir Inflow</u>

One required input into the ResSim Model is Baldhill Dam inflow. This record was acquired from the USACE St. Paul District Water Control Website (WCWS). Inflow values presented on the WCWS are back calculated using measured outflows and pool elevation. These calculations do not account for wind-wave effects on the pool or evaporation. As can be seen from the inflow record displayed in **Figure 4**, there are negative inflow values. This is representative of when pool evaporation exceeds inflow into the reservoir.

<u>1.1.3 Local Flow</u>

Ford Consulting computed their local flow values using an HMS model. Because a continuous HMS model is not available for the basin it is necessary to use an alternative means of estimating these local flows. Local flow records must be developed between Baldhill Dam and Valley City, as well as between Valley City and Lisbon.

These local flow records can be generated by acquiring gaged flow measurements at the upstream locations and routing them to the downstream gaged location. The routed flows at the downstream location are then subtracted from the gaged record at the downstream location to determine the local flow record.

Valley City does not have a complete flow record for the period of record (1942-2009). Stage data is available at Valley City for the majority of the missing portion of the flow record. A rating curve relating discharge and stage can be developed for Valley City. The rating curve, displayed in **Figure 6**, was created using NWS and USGS data. For the dates when neither discharge nor stage data was recorded a linear relationship can be used between the discharge record at Baldhill Dam and the discharge record at Valley City. This relationship can be found in **Figure 7**.

1.1.4 ResSim Model Calibration

After making the necessary changes to the ResSim Model calibration runs were carried out for 2005-2009 (POR reflecting the 5 foot rise in storage capacity). **Figure 8** through **Figure 11** display a comparison between modeled flows and actual flows released from Baldhill Dam for 2005-2009.

Figure 12 displays simulated flows at Lisbon compared to gaged flows at the USGS gage at Lisbon for the period of record form 2005-2009. As can be seen from the figures the model does a relatively good job of simulating flow through the reservoir and routing that flow to Lisbon.

1.2 Model Reach: Lisbon to West Fargo

A HEC-HMS model was used to route flows generated by the ResSim model at Lisbon, ND to West Fargo, ND.

1.2.1 Breakout Flows

Pacific International Engineering developed a study entitled *Hydraulic Study of Sheyenne and Maple Rivers and Overflow* areas for FEMA. Although this study was never officially adopted, it describes breakout flows in this part of the basin. Breakout flows occur downstream of the Gol Bridge and just upstream of Kindred. Breakout flows from the right bank of the Sheyenne River discharge southeast and east beyond the Sheyenne River watershed and drain into the Wild Rice River. A portion of the breakout flows on the left bank reach I-94 and discharge through Cass County Drain 34. Drain 34 flows into Cass County, ND Drain 14, which drains into the Maple River near its confluence with the Sheyenne River.

Information is available regarding the Sheyenne breakouts based on the Pacific International Engineering (PIE) unsteady HEC-RAS model and the 2009 flood. This information is displayed in **Table 2** and **Table 3. Figure 13** and **Figure 14** display relationship describing breakout flows just upstream and just downstream of Kindred, ND. The PIE model was used during the 2009 flood to assist with National Weather Service (NWS) forecasts. The PIE model based breakout forecasts are displayed in **Table 2** and **Table 3** (highlighted in yellow). In 2009, Southeast Cass County Water Resource District contracted with the USGS to gage flows at the breakout locations. The measured flows are also displayed in **Table 2** and **Table 3** (highlighted in green). As can be seen by comparing the modeled versus gaged values, the PIE model does a relatively good job of predicting the magnitude of breakouts from the Sheyenne River upstream and downstream of Kindred.

Table 2. Upstream Breakout Flow Relationship

Upstream Breakouts - Gol Bridge to Kindred							
Unsteady PIE Model HEC-RAS Model Results							
	Gol Bridge	Left Breakouts	Right Breakouts	Kindred	Total	Left	Right
10-Year	3,456	0	0		0	0%	0%
50-Year	5,768	207	13		220	94%	6%
100-Year	7,342	788	788		1576	50%	50%
March-April 2009 modeled based on NWS forecast hydrographs	8,950	1,179	1,924	5,847	3103	38%	62%
500-Year	11,929	1,963	4,030		5993	33%	67%
Actual 2009 based on Gage Records and Measurements							
2009 based Gage records and Measurements	8,700			5,770	2,930		
	Measurement 4/23/09			Mean Daily 4/23/09			

Table 3. Downstream Breakout Flow Relationship

Downstream Breakouts - Kindred to Horace							
Unsteady HEC-RAS Model Results							
	Kindred Bridge	Left Breakouts	Right Breakouts		Total	Left	Right
10-Year	3,418	0	0		0	0%	0%
50-Year	5,528	237	804		1,041	23%	77%
100-Year	5,746	327	880		1,207	27%	73%
March-April 2009 modeled based on NWS forecast hydrographs	5,845	383	907	4,555	1,290	30%	70%
500-Year	5,933	486	944		1,430	34%	66%
Actual 2009 based on Gage Records and Measurements							
2009 based Gage record and Measurements	5,770			4,550	1,220		
	Mean Daily 4/23/09			Mean Daily 4/25/09			

Breakout flows were modeled in HEC-HMS as diversion structures. Flows are routed from Lisbon to Gol Bridge. At Gol Bridge a diversion structure applies a breakout flow relationship based on the values in **Table 2**. Flows breaking out of the left bank are routed into Drain 14. Flows breaking out of the right bank are assumed to leave the study area. Residual flows are routed to Kindred. At Kindred local flow is added to the run-of-the-river flow and routed through a second breakout relationship based on the values in **Table 3**. Flows breaking out of the left bank are routed back into the Sheyenne River just upstream of the confluence of the Maple River. Flows breaking out of the right bank are assumed to leave study area. Residual flows are routed to West Fargo.

1.2.3 Routing

1.2.3.1 Lisbon to Gol Bridge/ Kindred

Ford Consulting's HEC- ResSIM model contains Muskingum-Cunge routing for the Sheyenne River from Lisbon up to Gol Bridge. Because the model was already calibrated, the routing parameters from the Ford HEC-ResSIM model were adopted for this reach in the HEC-HMS model. Because Gol Bridge and Kindred are located in close proximity of each other it is not necessary to route flows between these two locations. Instead, a direct transfer can be utilized.

1.2.3.2 Kindred to West Fargo

Modified Puls routing is used to route flows between Kindred and West Fargo. The storage discharge relationship necessary to utilize Modified Puls comes from a steady state HEC-RAS modeled developed by the USACE St. Paul District. The storage discharge relationship associated with the diversion is adopted for the reach between Kindred and West Fargo.

1.2.3.3 Kindred to Horace

The HEC-HMS model routes flow from Kindred to West Fargo without accounting for any change in routing at the location of the USGS gage at Horace, ND. If necessary, routing can be broken up at Horace using Muskingum-Cunge Routing to route flow from Kindred to Horace. The eight point cross section required to apply Muskingum Cunge routing comes from the *Sheyenne River Geomorphology Study*. Modified Puls routing can then be applied to route the flows from Horace to West Fargo. The storage discharge relationship necessary to utilize Modified Puls comes from a steady state HEC-RAS modeled developed by the USACE St. Paul District.

1.2.4 Available Discharge Data

A chart of all USGS gages located in the Lower Sheyenne River Basin along with their respective period of record is displayed in **Figure 5.**

USGS gage 05059500 Sheyenne River at West Fargo, ND includes combined flows from the Sheyenne River at West Fargo (USGS gage 05059500) and the Sheyenne River Diversion at West Fargo (USGS gage 05059480). The USGS gage at West Fargo Diversion also includes the diverted flows from the Horace diversion. The West Fargo Diversion and the Horace to West Fargo Diversion are interconnected. The West Fargo Diversion diverts flow from the Sheyenne River around West Fargo. The Horace to West Fargo Diversion diverts water from the Sheyenne River around Horace to the West Fargo Diversion.

USGS gage 05059300 Sheyenne River above Sheyenne River Diversion near Horace, ND represents the total Sheyenne River flow immediately upstream from the Horace flood Diversion. USGS gage 05059310 Sheyenne River Diversion near Horace, ND records the flow that is diverted from the Sheyenne River at this location. When flows are greater than about 1,000 cfs at Sheyenne River above Sheyenne River Diversion near Horace (station 05059300), water is diverted in order to control discharges downstream. The diverted flow returns to the Sheyenne River main channel at a location about 13 mi downstream, below the city of West Fargo.

USGS gage 05059500 Sheyenne River at West Fargo, ND is therefore representative of natural channel flow + diverted flows at West Fargo, ND + diverted flows at Horace.

1.2.5 Local Flows

There is a significant local drainage area associated with the Sheyenne River reaches between Lisbon and Kindred and between Kindred and West Fargo. The local flow records associated with these drainage areas are generated by routing gaged flow at the upstream locations to the downstream gaged locations. The flows routed to the downstream locations are subtracted from the gaged record at the downstream locations to determine the local flow records.

For the 1997, 2001, 2006 and 2009 spring flood events Ford Consulting develop HEC-HMS based local flow records for the reaches between Baldhill Dam and Gol Bridge. This data was utilized to generate flow hydrographs at Gol Bridge for these events.

1.3 West Fargo to the Confluence of the Red River of North

The following Straddle Stagger routing parameters are used to route flows from West Fargo to the mouth of the Sheyenne River in accordance with the 1988 USACE *Timing Analysis*.

Straddle: 5, 760 min

Stagger: 1, 440 min

Table 4 contains the local area related to each of the reaches on the Sheyenne River between West Fargo and the confluence of the Sheyenne River with the Red River of the North. Because the local area is only approximately 4 square miles, it was determined that the amount of local runoff can be considered negligible for each of these reaches.

Table 4. Sheyenne River below West Fargo

Sheyenne River	
Reach	**Local Area (Sq Mi)**
W. Fargo to Mouth of Maple River	2
Maple R to the Rush R	1
Rush R to Conf w/ Red River	1
Total Local Area	**4**

1.4 Drain 14

Cass County Drain 14 flows north from near Kindred, ND to the confluence of the Maple River with the Sheyenne River. The drain picks up approximately 126 square miles of local area flow, as well as breakout flows from the Sheyenne River near Kindred, ND and the Maple River near Durbin, ND.

At the request of the Southeast Cass County Water District the USGS has installed a gaging station at Drain 14 near Mapleton, ND (USGS 465213097003901). This gage recorded flow data during the 2010 flood event. As can be seen from **Figure 15** a significant amount of flow is carried through the drain during large flood events. During the 2010 spring flood event a peak of 1,670 cfs of flow was recorded at the Drain 14 gage. A map that includes Drain 14 can be found in **Figure 16**.

1. 5 Maple River

The Maple River is a tributary of the Sheyenne River. Maple River flows are regulated by the Maple River Dam. The Maple River Dam is located near Sheldon, ND.

Maple River Dam became active in fall 2006. In order to generate a homogenous record at Mapleton, ND an HEC-HMS model was developed for the reach of the Maple River between the USGS gage at Enderlin to the USGS Gage located near Mapleton, ND (USGS Gage 5056000).This model can be used to generate both a regulated and unregulated continuous flow record at Mapleton, ND. A detailed description of the methodology used to develop this model can be found in **Appendix A-4b**.

1.5.1 Breakout Flows

Based on conversations with Moore Engineering and their field experience with the Maple River watershed, it can be assumed that during large flood events, like the 2009 event, breakout flows occur between the Maple River Dam and Mapleton. Much of these breakout flows occur near Durbin, ND and are likely on the order of 1,000-3,000 cfs. These breakout flows re-enter the

Sheyenne River prior to its confluence with the Red River of the North. The breakout flows near Durbin,ND drain into Cass County Drain 14.

1.5.2 Local Flow Determination

Using a calibrated HMS model, flows are first routed to the Mapleton without inputing a inflow record representing local flow between the dam and Mapleton. The resulting flow at Mapleton is subtracted from the USGS gaged record at Mapleton to determine the local inflow record between the Maple River Dam and Mapleton. This methodlogy includes breakout flows within the determined local flow record (along with any error associated with the model).

1.5.3 Model Shortcomings

Unless these breakout flows are defined and re-routed back into the Sheyenne River, the flow at the Sheyenne's confluence with the Red River will be underestimated for large events. There is no relationship representative of the breakout flows at Durbin. The magnitude of these breakouts will likely be mitigated to some degree by the Maple River Dam.

1.5.4 Mapleton to Maple River Confluence

In order to tie the Maple River modeling effort discussed in the previous section with the rest of the Sheyenne River model it is necessary to route modeled flows from Mapleton, ND to the confluence of the Maple River with the Sheyenne River.

1.5.4.1 Routing

Flows are routed from Mapleton to the confluence of the Maple River with the Sheyenne River using Muskingum-Cunge, eight point cross section routing.

1.5.4.2 Maple River Watershed Local Flows

Local flows for the drainage area between Mapleton and the Maple River's confluence with the Sheyenne River, as well as the local flows associated with Drain 14, can be estimated using a drainage area ratio and the Amenia, ND gage as a reference gage. The values in **Table 5** can be used to estimate local flow.

Table 5. Drainage Areas & Drainage Area Ratios- Sheyenne River Watershed

Location	Drainage Area (sq. miles)
Drain 14 Drainage Area - Sheyenne River Watershed	125.50
Local Drainage Area Durbin, ND (Maple River) to Conf. of Maple River with the Sheyenne River	19.70
USGS Gage Site 05060500 Rush River at Amenia	116
Drain 14 Ratio with Amenia , Rush River	1.08
Local Area Flow Ratio with Amenia, Rush River	0.17

1.6 Rush River

The Rush River is a tributary of the Sheyenne River. There is a USGS gage located on the Rush River at Amenia, ND. Recorded flows from the gaging station at Amenia are routed to the confluence of the Rush River with the Sheyenne River using Straddle Stagger Routing parameters based on the Corps of Engineers 1988 *Timing Analysis*. The Straddle Stagger parameters utilized in the HEC-HMS model are:

Straddle: 540 min

Stagger: 1, 760 min

Local Area flow between the Amenia gage and the confluence of the Rush River with the Sheyenne River are determined using Amenia as a reference gage. The drainage areas used to develop the relationship with the reference gage, along with the ratio itself can be found in **Table 6**.

Table 6. Local Area Flow- Rush River

Rush River Local Flows	
Reference Gage:	Amenia
Location	Drainage Area (sq. miles)
Amenia Gage	116
Rush River (incl. Lower Rush River D.A = 66 sq. miles)	238
Local DA Amenia to Conf. Rush River	122
Adopted Drainage Area Ratio:	1.05

1.7 Sheyenne River Breakout flows

A significant amount of flow breaks out from the Sheyenne and Maple Rivers during flood events. According to minutes recorded at the Maple River Water Resource District meeting breakout flows are known to occur along the Lynchburg Channel, Buffalo Creek, the Maple River and Drain 14. **Figure 17** through **Figure 23** display aerial photographs depicting breakouts during the 1997 flood event. These photographs give insight into the volume of water that is leaving the channel during flood events. The effects of breakouts are dispersed from near the confluence of the Maple River with the Sheyenne River to Argusville, ND.

Although the breakout flows that occur on the Sheyenne River near Kindred do add to peak flows on the Red River in 1997, the breakout flows know to occur on the Sheyenne River near Kindred, ND do not significantly add to the peak on the Red River of the North in 2009. This can be concluded because USGS gaged flows at Lisbon and Kindred do not reach bankfull magnitudes until later in April. The Red River of the North reached its flow crest in March.

2. Fargo to Halstad RRN HMS Modeling

In addition to the Sheyenne River there are three other significant tributaries that reach their confluence with the Red River of the North (RRN) between Fargo and Halstad: the Buffalo River, the Wild Rice River (Minnesota Side, WWR-MN) and the Elm River. **Figure 1** diagrams the study reach.

2.1 Tributary Flow

2.1.1 The Buffalo River

The Buffalo River enters the Red River of the North about 1 mile west of Georgetown, MN. It is 88 miles long and has a drainage area of about 1, 190 square miles.

2.1.1.1 Discharge Data

USGS gage 05062000 near Dilworth, MN provides tributary flow for the Buffalo River. The Dilworth gage has a drainage area of 975 square miles. The daily discharge record at Dilworth has a period of record from 1930 to present.

2.1.1.2 Routing

Because there is a significant distance between the USGS gage at Dilworth and the Buffalo River's confluence with the Red River of the North, it is necessary to use straddle stagger routing to route flows. The following Straddle Stagger routing parameters are based on the *1988 USACE Timing Analysis*, as well as model calibration:

Straddle: 4,320 min
Stagger: 2,880 min

2.1.1.3 Local Area Flow

Local Area Flow between for the Buffalo River between Dilworth and the Buffalo River's confluence with the Red River of the North is determined using a drainage area ratio. The Dilworth gage can be used as a reference gage. **Table 7** displays the drainage areas used and the ratio utilized in developing a local flow record for the Buffalo River.

Table 7. Buffalo River Local Flows

Location	Drainage Area (sq. miles)
Dilworth Gage	975
Buffalo River	1,190
Local DA Dilworth to Conf. Buffalo River	215
Adopted Drainage Area Ratio (Dilworth)	0.22

2.1.2 The Elm River

2.1.2.1 Discharge Data

There is only one USGS station located on the mainstem of the Elm River with a significant period of record: USGS Gage 05062200 located near Kelso, ND. This gaging station recorded daily streamflow measurements between 1955 and 1986. The drainage area associated with this gage is 199 sq miles.

Field measurements were taken at USGS gage site 471924097014701 on the North Branch of the Elm River at Kelso, ND and on the mainstem of the Elm River at USGS gage site 05062250 during the 2010 flood event. The locations of these gaging sites are displayed in **Figure 24**.

The long term streamflow record measured near Kelso on the mainstem can be combined with the 2010 field measurements at Grandin because these two gage sites are located close together. A regression analysis carried out between USGS gage 05066500 located on the Goose River at Hillsboro, ND and the combined observed flow record at Grandin/ Kelso yields a linear relationship. There is a relatively good correlation between the augmented streamflow record at Kelso and the streamflow record at Hillsboro for their concurrent period of record 1955-1986, 2010. This relationship, displayed in **Figure 25**, is used to develop a streamflow record representative of the Elm River near Kelso.

2.1.2.2 Routing

Using Steady State HEC-RAS Houston Engineering determined that there is a lag of approximately one day from the Elm River at I-29 to the Elm's confluence with the Red River of the North. I-29 crosses the Elm River near Grandin, ND, therefore a 1-day lag was used when routing flows from Grandin/Kelso to the mouth of the Elm River.

2.1.2.3 Local Flow Area

The local flow record for the Elm River can be estimated using a drainage area ratio. USGS gage 05066500 located on the Goose River at Hillsboro can be used as a reference gage. The drainage areas associated with the Elm River at Kelso/Grandin, the local drainage area, the Hillsboro drainage area, as well as the resulting drainage area ratio can be found in **Table 8**.

Table 8. Elm River Local Flow

Location	Drainage Area (sq. miles)
Kelso Gage (mainstem - [illegible]) USGS	199
Hillsboro Gage (Goose River)	1,093
D.A above Elm River	13,085
D.A Below Elm River	13,485
Elm River D.A	400
Local D.A	201
Adopted Drainage Area Ratio:	0.18

<u>2.1.3 The Wild Rice River- Minnesota</u>

The Wild Rice River- Minnesota flows westward until it enters the Red River of the North just south of Ada, MN. It is 160 miles long and has a drainage area of about 1, 650 square miles. USGS gage 05064000 at Hendrum, MN provides tributary flow for the Wild Rice River. The Hendrum, MN gage has a drainage area of 1, 560 square miles. The daily discharge record at Hendrum has a period of record from 1944 to present.

Based on the *1988 USACE Timing Analysis*, a 1-day lag should be applied to the flow record at the Hendrum gage in order to route flows to the confluence of the Red River of the North with the Wild Rice River .

2.2 Mainstem Routing & Local Flow

Although initially Modified Puls routing was considered, as can be seen in **Table 9,** Straddle Stagger is the adopted routing method on the mainstem of the Red River of the North. Using Straddle Stagger produces a better calibrated result. Straddle Stagger routing parameters are based on the *USACE 1988 Timing Analysis.*

Table 9. Mainstem Modeling

<table>
<tr><th rowspan="2">Reach</th><th rowspan="2">Routing Method (Straddle in days, Stagger in days)</th><th rowspan="2">Contributing Local Drainage Area (SQ MI)</th><th rowspan="2">Local Flow Determination</th><th colspan="2">Reference Gage</th><th rowspan="2">Drainage Area Ratio</th></tr>
<tr><th>Gage Location</th><th>Drainage Area (SQ MI)</th></tr>
<tr><td>Fargo to Upstream Sheyenne River</td><td>Straddle Stagger (3,1)</td><td>430</td><td>Drainage Area Ratio</td><td>Dilworth, MN</td><td>975</td><td>0.44</td></tr>
<tr><td>Downstream Sheyenne River to Upstream Buffalo River</td><td>Direct Transfer</td><td>210</td><td>Drainage Area Ratio</td><td>Dilworth, MN</td><td>975</td><td>0.22</td></tr>
<tr><td>Downstream Buffalo River to Upstream Elm River</td><td rowspan="2">Straddle Stagger (5, 2)</td><td>350</td><td>Drainage Area Ratio</td><td>Dilworth, MN</td><td>975</td><td>0.36</td></tr>
<tr><td>Downstream Elm River to Upstream Wild Rice River-MN</td><td>30</td><td>Drainage Area Ratio</td><td>Hendrum,MN</td><td>1,560</td><td>0.02</td></tr>
<tr><td>Downstream Wild Rice River-MN to Halstad</td><td>Direct Transfer</td><td>40</td><td>Drainage Area Ratio</td><td>Hendrum, MN</td><td>1,560</td><td>0.02</td></tr>
</table>

As is described in **Table 9,** drainage area ratios can be used to determine the local flow associated with reaches along the mainstem of the Red River of the North. Contributing drainage areas for mainstem locations are from the *USACE 2001 Final Hydrology Report: Hydrologic Analyses, the Red River of the North Main Stem.* Areas associated with reference gages are from the USGS.

Because local area flow in the Red River Basin runs off relatively slowly and is often attenuated by the effects of overland storage straddle stagger routing (4, 4) is applied to local runoff on the mainstem of the Red River of the North.

3. Model Calibration- Mainstem of Red River between Fargo & Halstad Incl. Sheyenne River

3.1 Discontinuities Associated with the Mapleton Gage

3.1.1 Available Data at Mapleton

There are two gages located near the city of Mapleton, ND on the Maple River. The original gage is (USGS 50561000) located downstream of Mapleton. An additional gage was installed upstream of Mapleton (USGS 50560000) in order to avoid recording breakout flows. During large flood events on the Maple River there is a significant difference between the magnitudes of flow recorded by these two gages as is apparent from the 2006 flood hydrograph found in **Figure 26**. The timing of the Maple River usually coincides with the timing of flow on the Red River of the North. A misrepresentation of flow on the Maple River can significantly affect modeled flows downstream.

3.1.2 Breakout Flows on the Maple River

There is evidence of flow being lost between Enderlin and Mapleton in 1997 and 2009 as is displayed in **Figure 27** and **Figure 28**. In 1997 there is a double peak observed at Enderlin, but not at Mapleton. In 2009 the second peak at Enderlin is approximately 1,000 cfs greater than the corresponding peak on the Maple River at Mapleton. The loss of flow between the two locations can likely be attributed to breakout flows and would presumably add to the peak in 1997 and to the receding limb of the flow hydrograph in 2009 at Halstad.

3.2 Sheyenne River Calibration to Harwood

Between 1996 and 2010 instantaneous annual peaks and National Weather Service (NWS) field measurements have been taken at USGS gage site 05060400 located on the Sheyenne River at Harwood, North Dakota. This gage is located downstream of West Fargo and downstream of the Maple River. An accurate calibration at this site implies that breakout flows near Kindred, routing and local flows are being captured adequately. The field measurements taken at the

Harwood gage are of varying quality, but do provide some insight into how well the HEC-HMS model is calibrated. As can be seen from **Figure 29**, **Figure 30** and **Figure 31**, the model calibrates relatively well to the observed measurements at Harwood.

Since the data observed at Harwood is based on field measurements and because Harwood is located at a point on the Sheyenne River that experiences a great deal of backwater effects and breakout flows, measurements taken at this location likely include a degree of error and must be considered critically. In 2009 a bimodal peak was observed on the Sheyenne River. As can be seen in **Figure 31**, the observed data at Harwood only provides insight into the timing and magnitude of the first peak on the Sheyenne River.

During 1997 it is likely that the flow measurements made at Harwood on the 22nd and 23rd of April are erroneous. The observed flows recorded on the 16th of April and the 24th of April are greater than the observed flows observed on the 22nd and 23rd of April. It is unlikely that the flows at Harwood decreased to the observed values recorded on the 22nd and 23rd of April displayed in **Figure 29**.

3.3 Calibration Events

The model was calibrated to the 1997, 2006 and 2009 events because these events are being used to develop design parameters for the Fargo Moorhead Metro Feasibility Study. As can be seen from **Figure 32**, **Figure 33**, and **Figure 34** the model calibrates relatively well to these three events.

The model captures the peak, timing and volume of the 2009 event well. The tail end of the 2009 event doesn't calibrate well to the observed USGS flows at Halstad.

The 2006 run overestimates flow by approximately 6, 000 cfs, but captures the timing and volume of the event accurately.

The 1997 event also underestimates flow by around 7,000 cfs, but captures the timing and volume of the event accurately.

4. Conclusions

For the Fargo Moorhead Metro Feasibility Study this model and the information presented in this report can be used to generate flow hydrographs at points of interest in this portion of the basin. These hydrographs can be used as input into the Unsteady RAS model being developed to assess flow through the basin.

Building the model provides insight into the basin's hydrologic properties. Based on model calibration the following conjectures can be made concerning timing and flow magnitude in the basin:

- There is a significant difference between using the two different Mapleton gages if you use USGS 50561000 you will underestimate the peak at Halstad. Because this is the only gage available in 1997 this likely contributes to the model underestimating the peak in 1997.
- Local Flow reaches the mainstem of the Red River of the North slowly and attenuates significantly.
- For the majority of years the breakout flows near Durbin, North Dakota do not appear to be significant (this could be either because of their timing or because of their magnitude) because they were not re-introduced into the Sheyenne River and the model still calibrated well. It is possible that they have a minimal effect on the model's ability to represent the 1997 and 2009 events.
- As the second peak on the Sheyenne River reached its confluence with the Red River of the North in 2009 it was attenuated significantly. The crest on the Sheyenne River is also prolonged due to backwater effects from the Red River.

For future studies this model provides for a means of adapting the Baldhill Dam ResSim model for continuous simulation and provides for a calibrated routing structure for future HMS models of the portion of the basin being considered. The model also provides for a means of creating a homogenous flow record for Lisbon and Mapleton which includes the regulatory effects of the 5' raise at Baldhill and the construction of the Maple River Dam, respectively.

References

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3. *Final Hydrology Report: Hydrologic Analyses the Red River of the North Mainstem Wahpeton/ Breckenridge to Emerson, Manitoba*. USACE St. Paul District. September 2001.
4. Google Earth. 2010. USDA Farm Service Agency.
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11. Jeffery J. Volk. Moore Engineering Inc. Sheyenne-Maple Flood Control: Maple River Dam.Red River Basin Commission 22nd Annual Conference. January 2005.
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13. *Volume I: Timing Analysis*. Technical Resource Service Red River of the North. USACE St. Paul District. March 1988.
14. West Consultants Inc. 2001. Sheyenne River: Geomorphology Study.

Figures

Figure 1. Red River Reach Fargo to Halstad

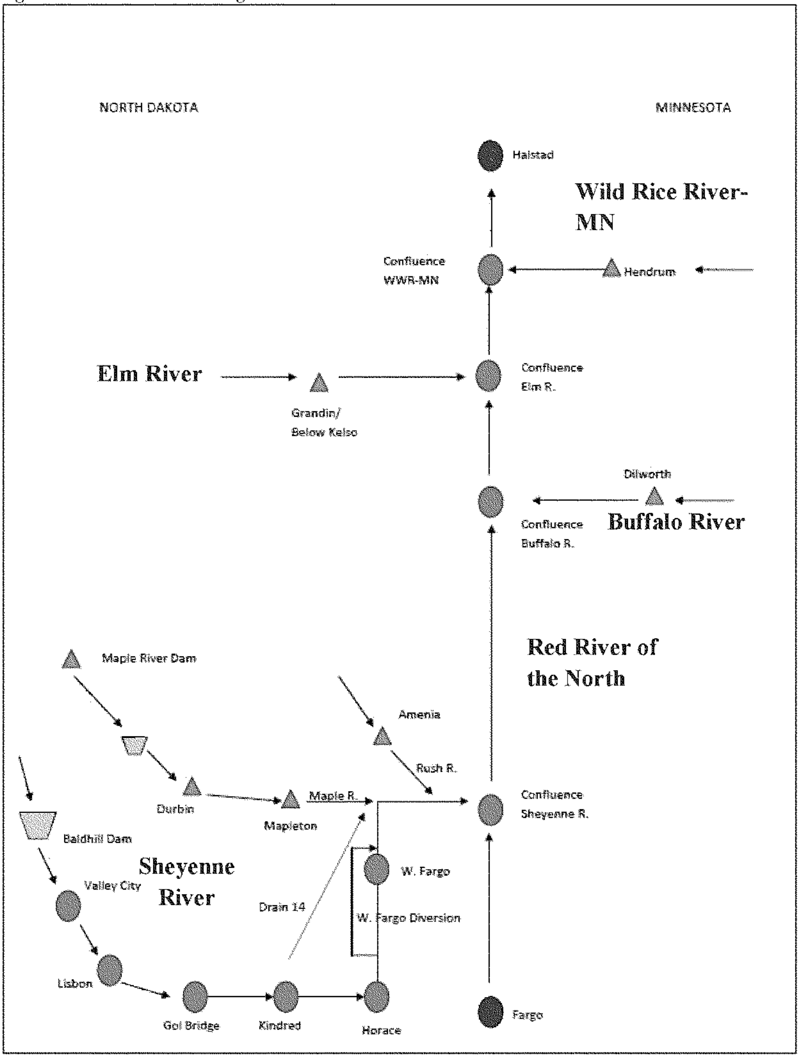

Figure 2. Ford ResSim Schematic

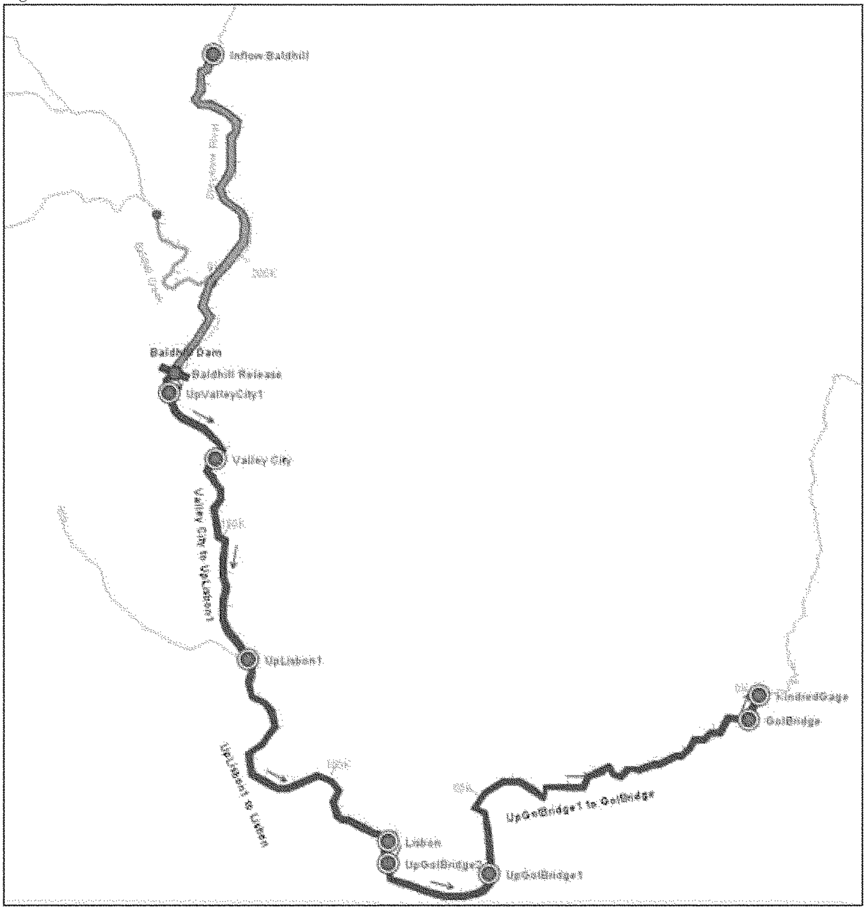

Figure 3. Snow Water Equivalent Record

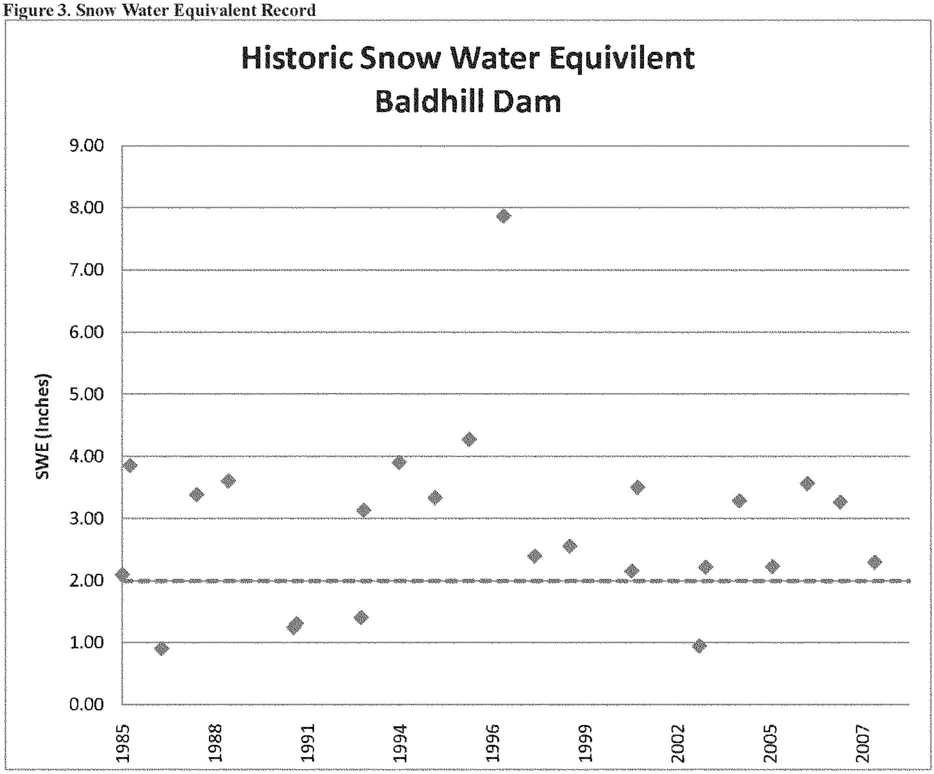

Figure 4. Inflow record into Baldhill Dam (USACE Water Control Website)

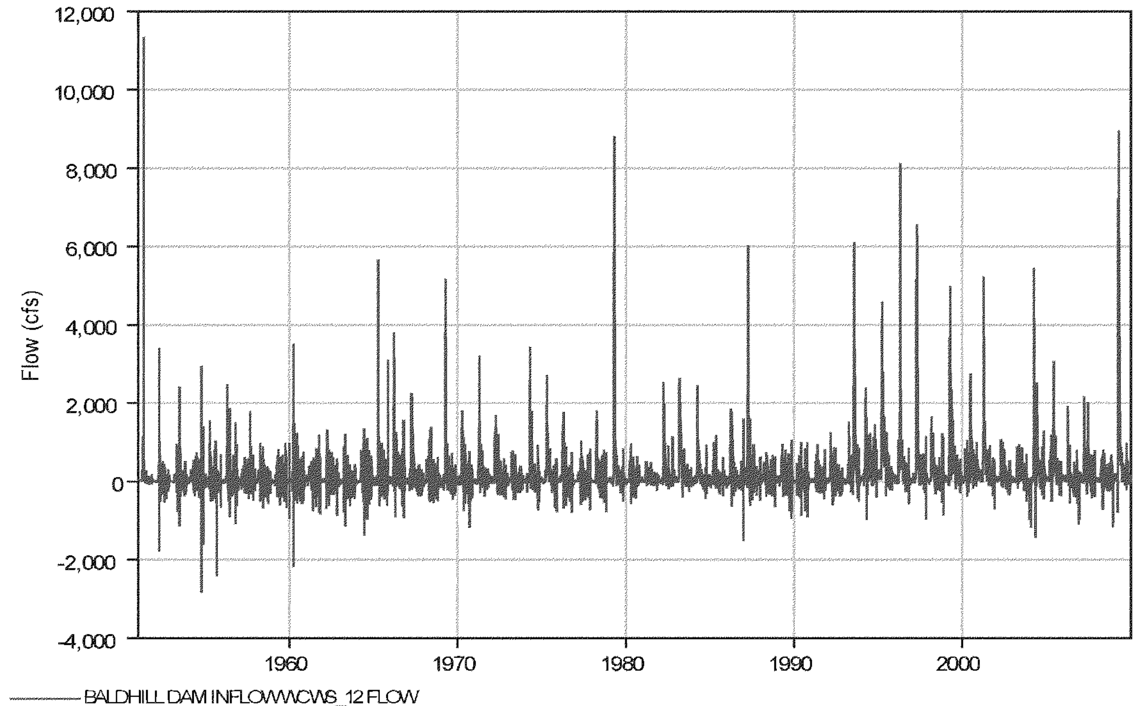

Figure 5. Available gage data Lower Sheyenne Basin

No data
Recording
Sporadic data

Regulation Placed into Effect (W. Fargo Diversion, Horace Diversion, Maple River Dam, Baldhill Dam)

Five foot Raise at Baldhill Dam

USGS GAGES IN THE SHEYENNE RIVER BASIN

	Amenia 5060500	Combine US & DS Mapleton 50560000/ 50561000	Enderlin 5059700	West Fargo 5059500	NR Horace Diversion 5059310	Kindred 5059000	Lisbon 9020204	Valley City 5058500	Baldhill Dam 5058000
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NOTES:	*Note: The upstream gage is the preferred gage... but only works sporadically. The gage was moved due to breakouts from the Sheyenne near Kindred*	*Note: There are two gages at W. Fargo. The other gage is at the diversion. We are using the one at W. Fargo. For this project we are assuming the diversion has no effect... there is some data for 1919*	*Note: there may be mean daily data back to 1980 somewhere... b/c there is inst. Annual peak data back to 1980. There is also a gage located at the diversion. This is the gage above the diversion. We are assuming the diversion has no effect*	*Sporadic data in '38, '19, and in '95-'02*	

Figure 6. Discharge-Stage Rating Curve for USGS gage at Valley City

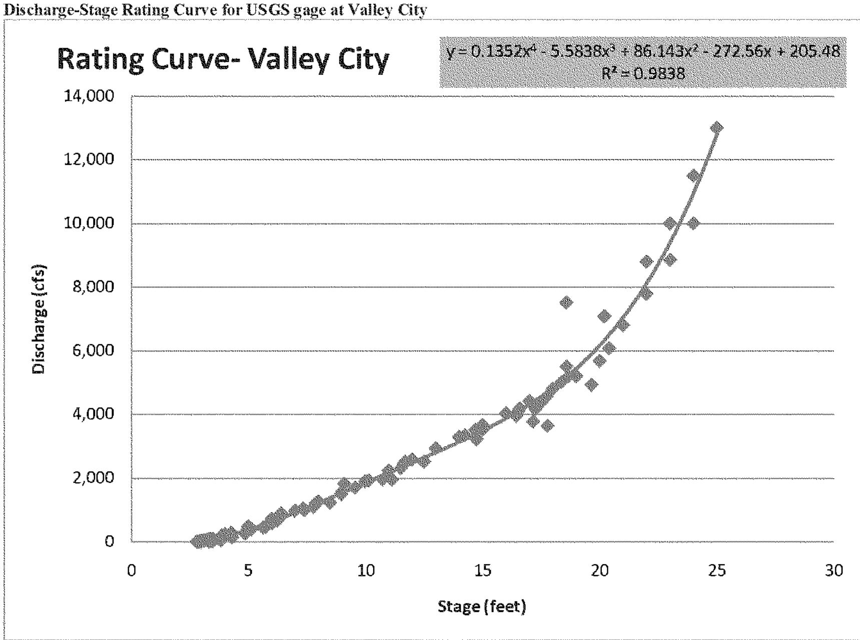


Figure 7. Linear Relationship between Baldhill Dam Discharges and Valley City Discharges

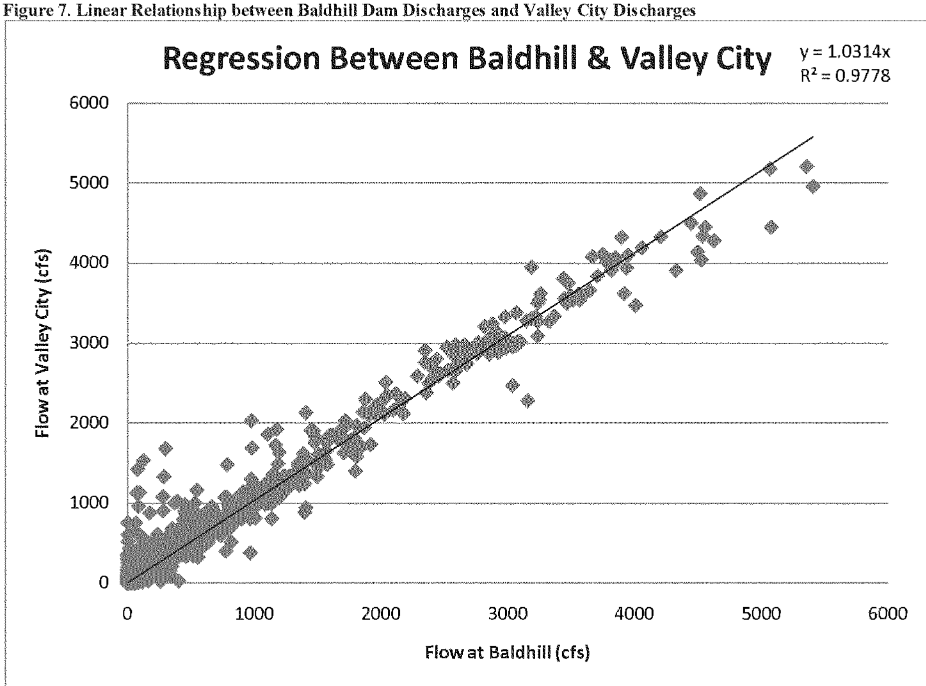


Figure 8. Calibration Outflow from Baldhill Dam for 2005: Blue = modeled flow & Red = Observed Outflows

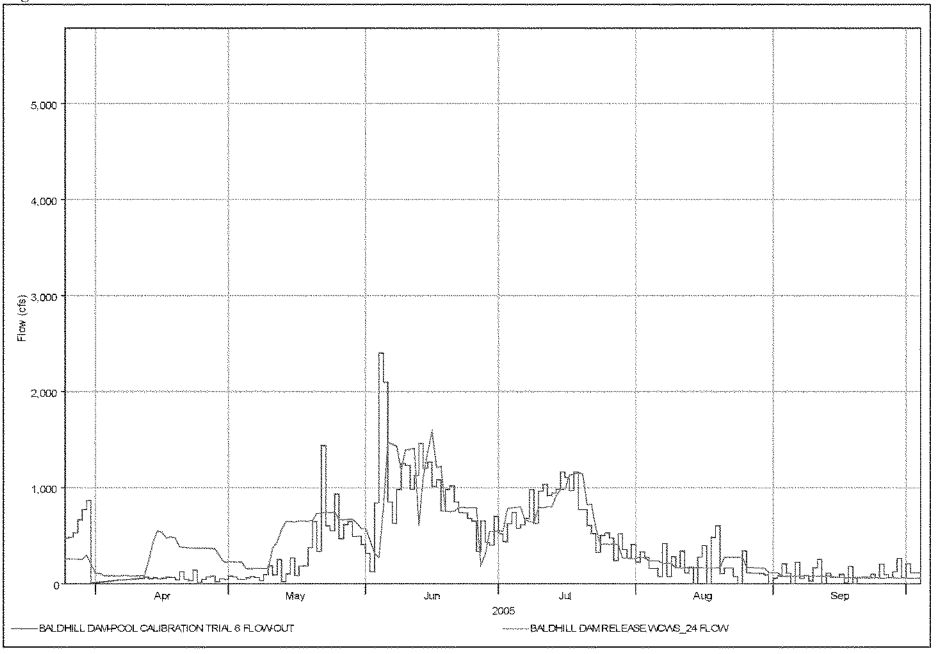
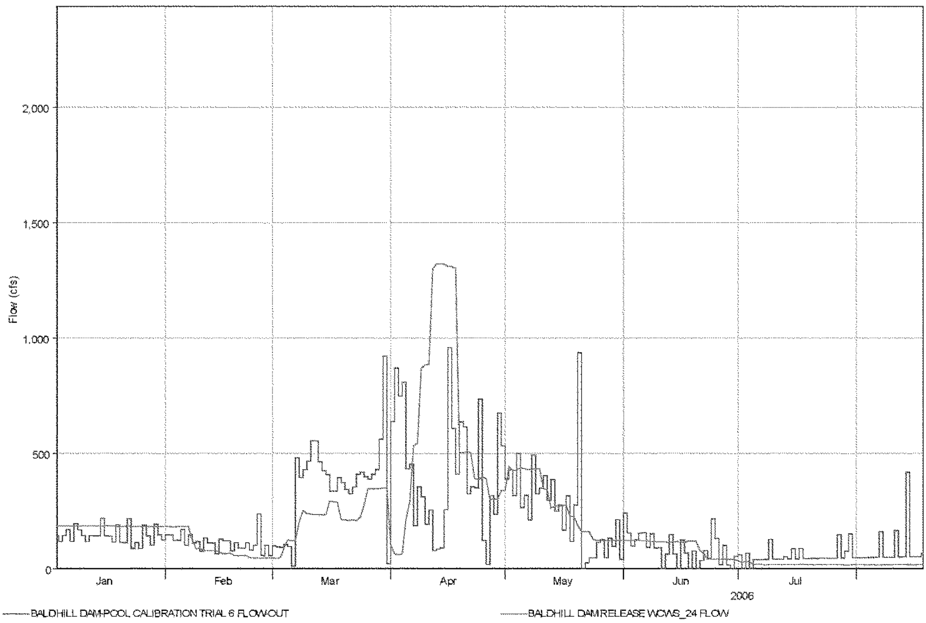


Figure 9 Calibration Outflow from Baldhill Dam for 2006: Blue = modeled flow & Red = Observed Outflows



2007

Figure 10. Calibration Outflow from Baldhill Dam for 2007: Blue = modeled flow & Red = Observed Outflows

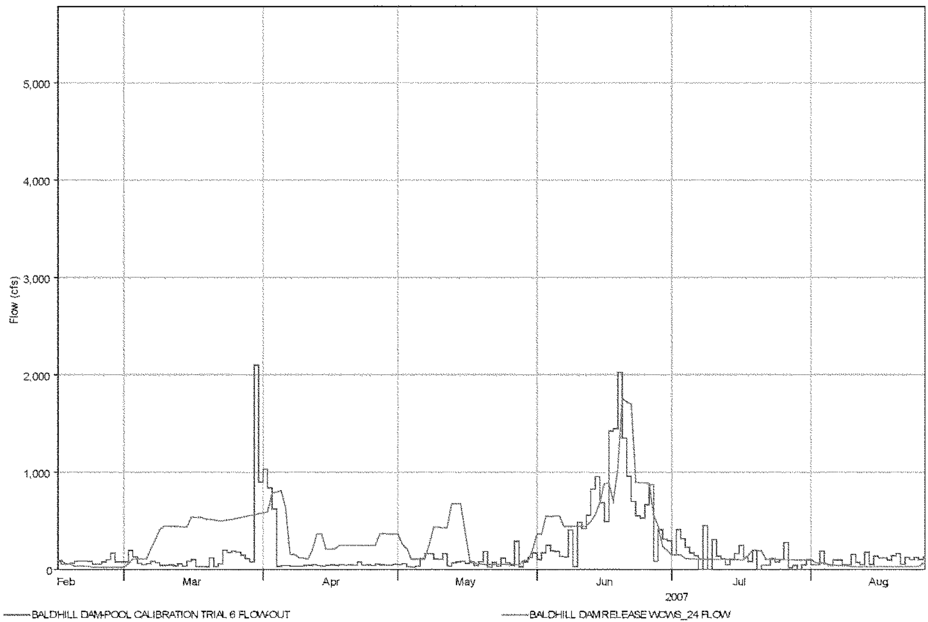


Figure 11. Calibration Outflow from Baldhill Dam for 2009: Blue = modeled flow & Red = Observed Outflows

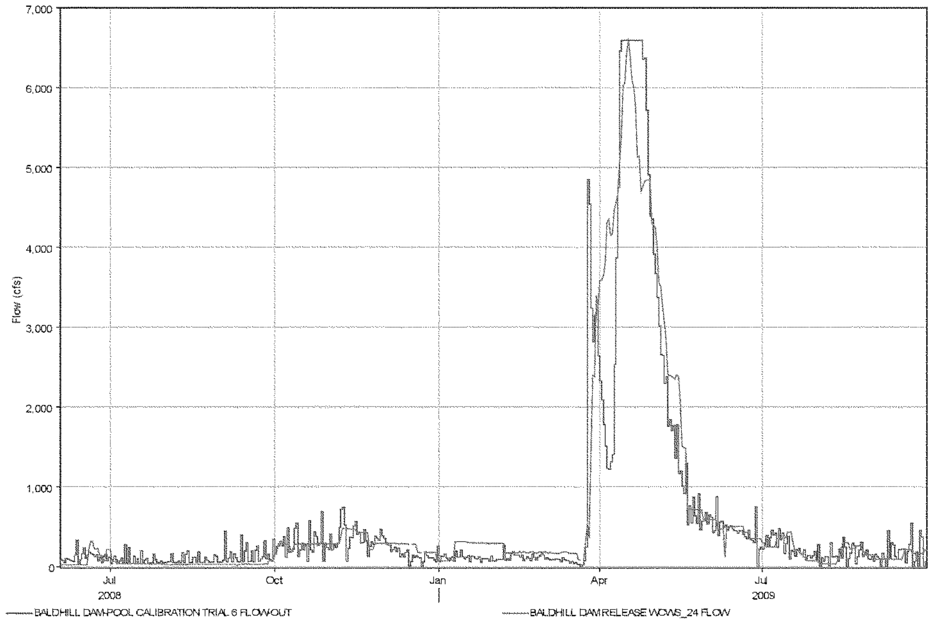


Figure 12. Calibration Run at Lisbon 2005-2009: Blue is modeled flow and red is gaged flow.

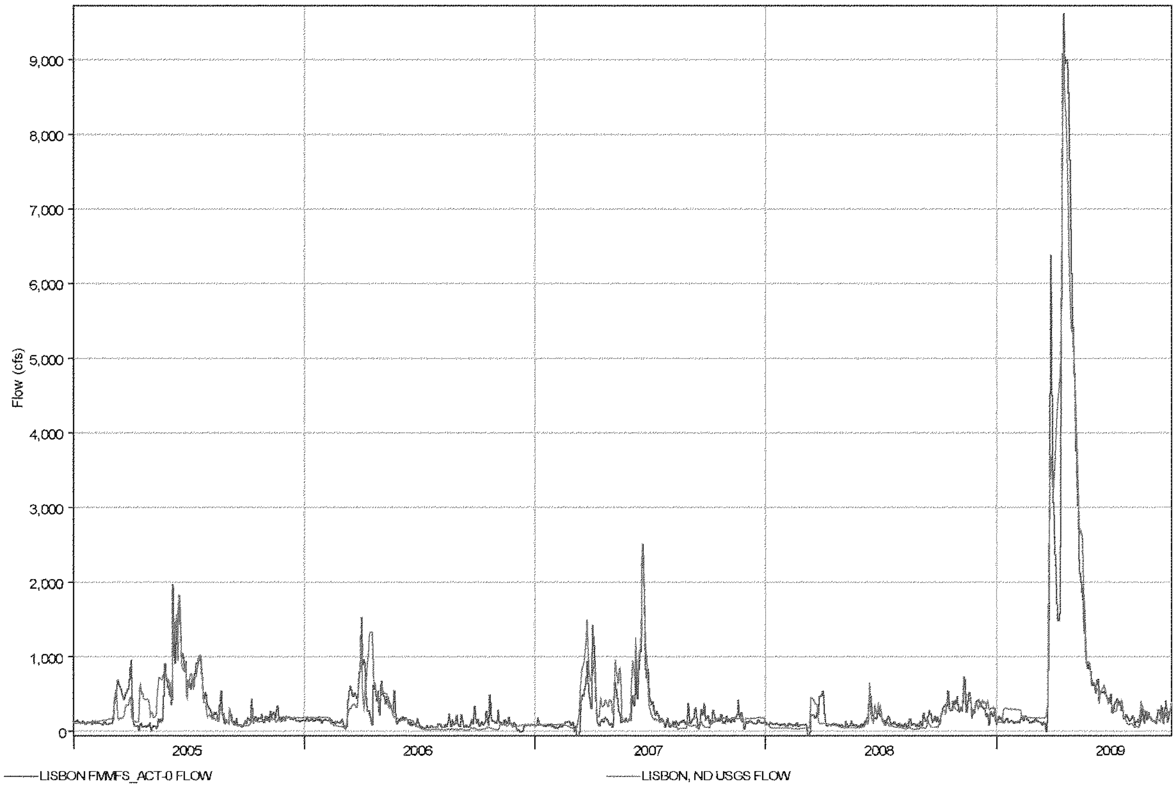


Figure 13. Upstream breakout relationship

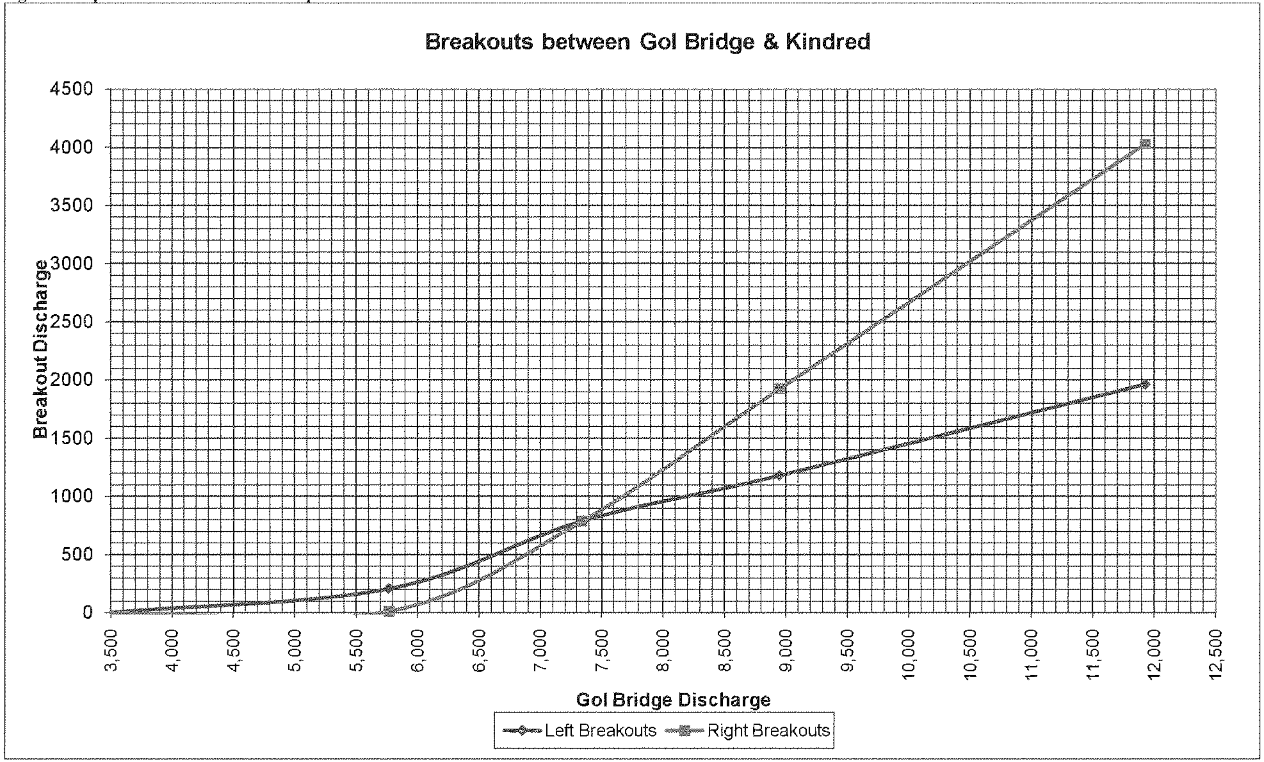


Figure 14. Downstream breakout relationship

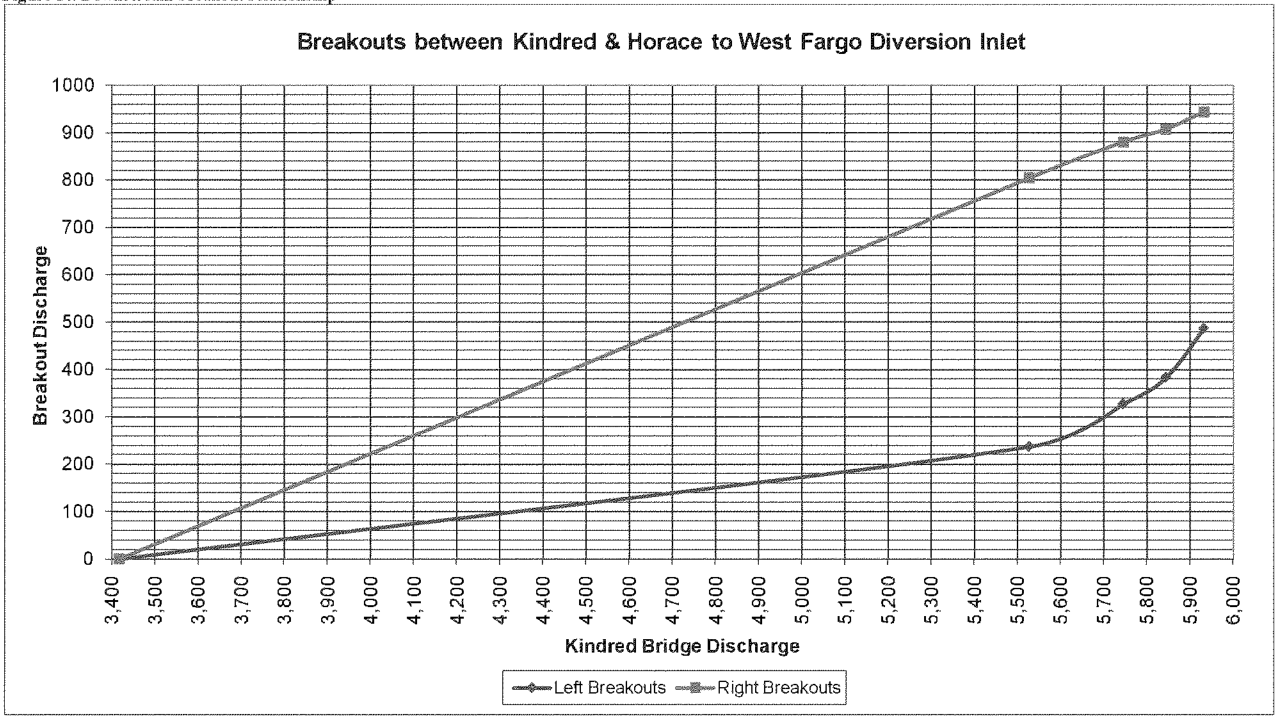


Figure 15. Drain 14 Near Mapleton looking north towards I-94.

Figure 16. Drain 14 Map (Cass County Website)

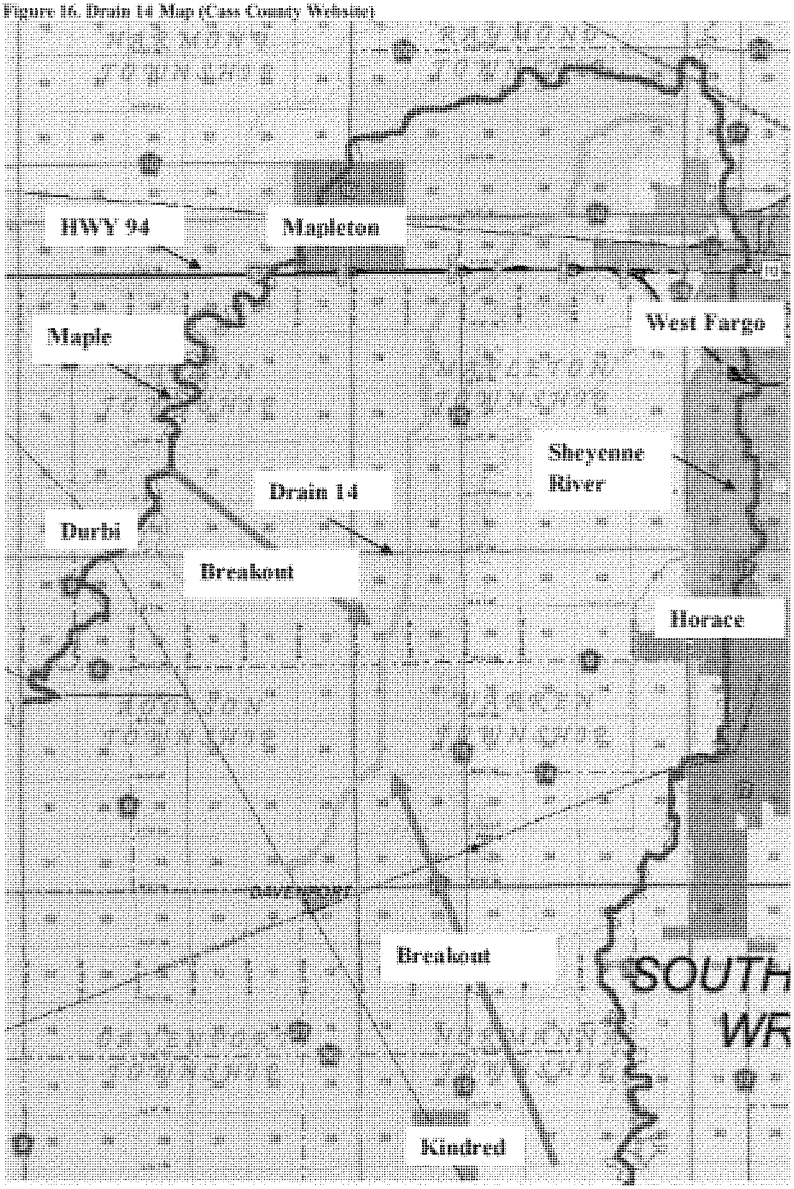


Figure 17. Breakout Flows looking Northwest, just southeast of Harwood, ND (Moore Engineering)

Figure 18. Breakout flows near the confluence of the Sheyenne River with the Maple River, Looking Northeast (Moore Engineering)

Figure 19. Breakout flows at Harwood, ND , Looking West (Moore Engineering)

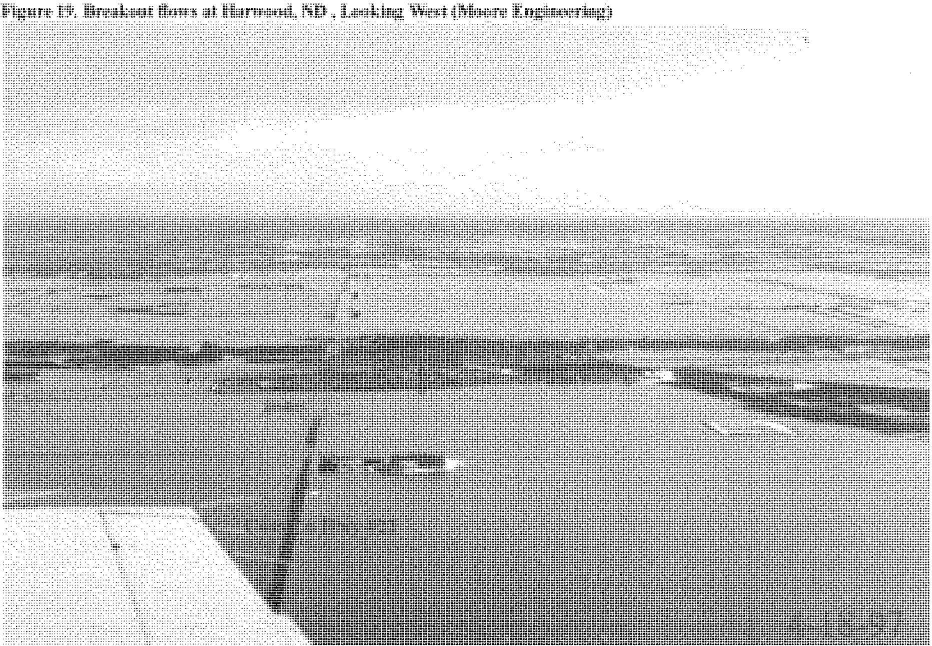


Figure 20. Breakout Flows Looking Northeast near the West Fargo Diversion (Moore Engineering)

Figure 21. Looking North (Moore Engineering)

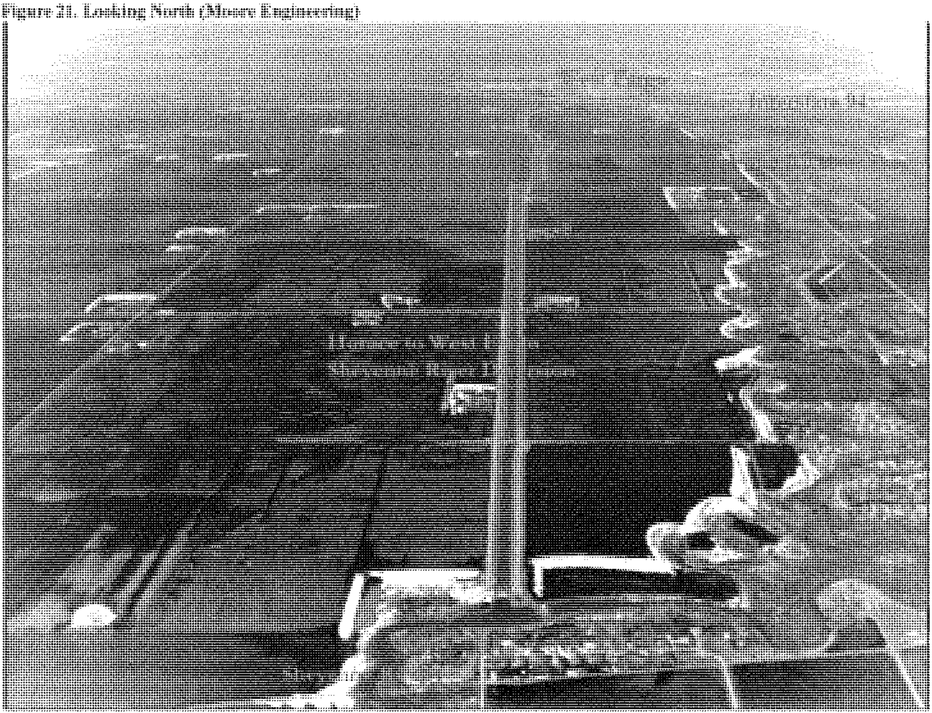


Figure 22. Looking Northeast (Moore Engineering)

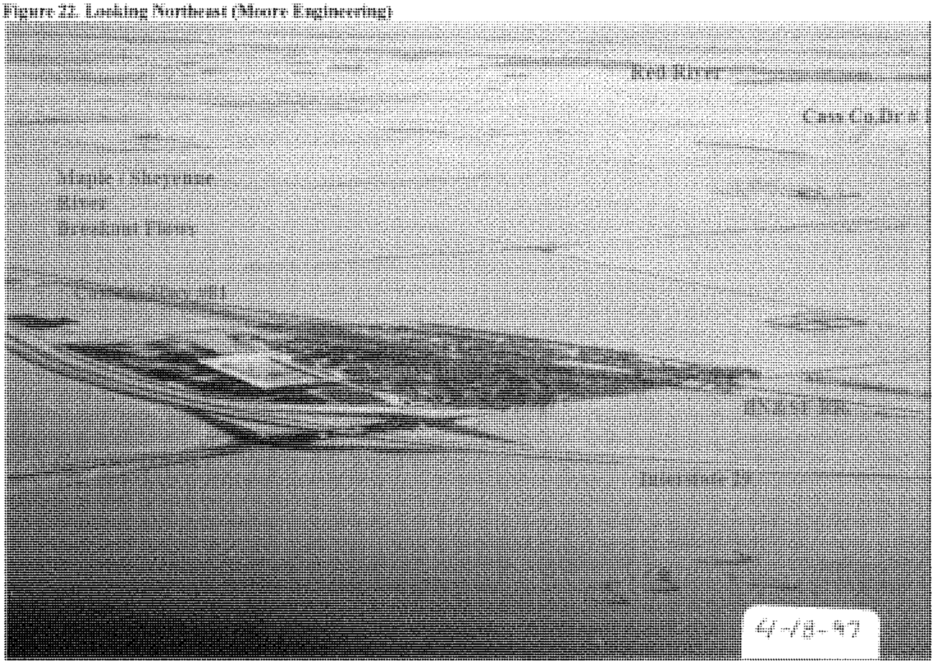


Figure 23. Geographical distribution of aerial photographs

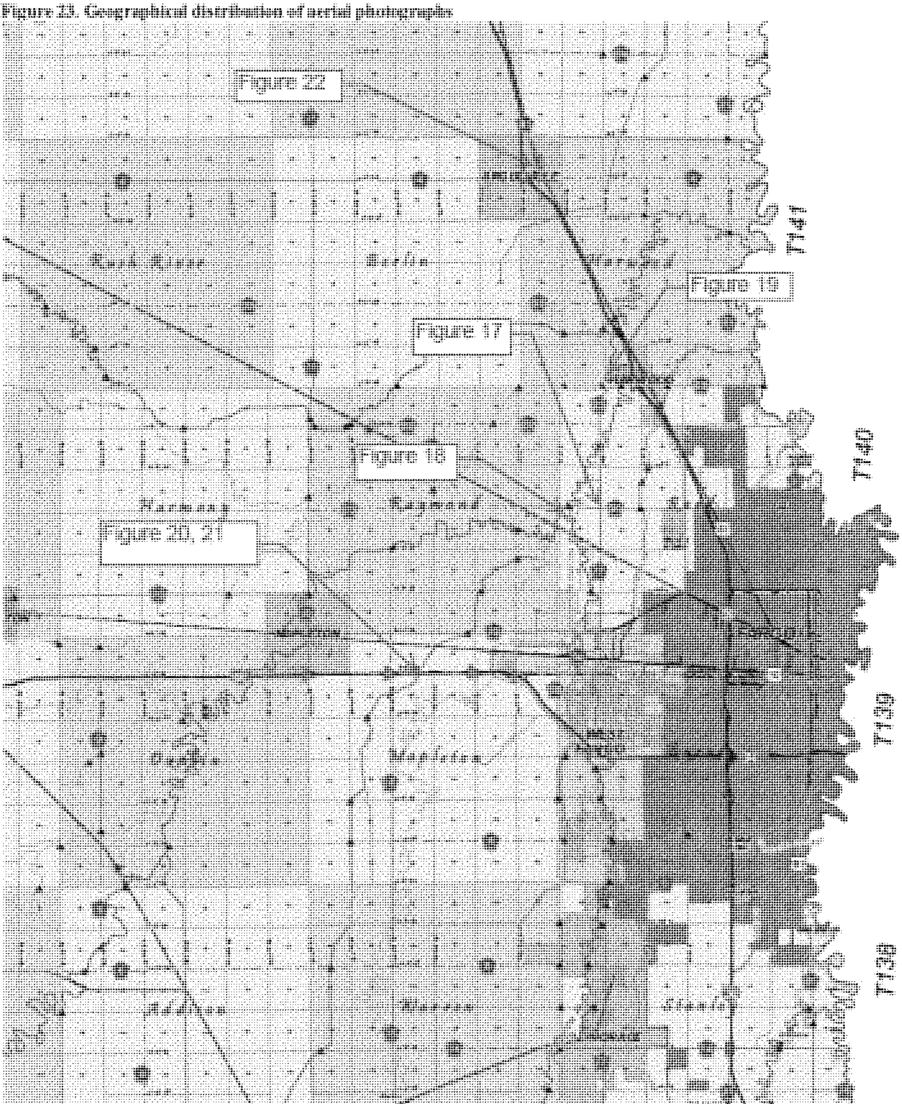


Figure 24. Elm River gages

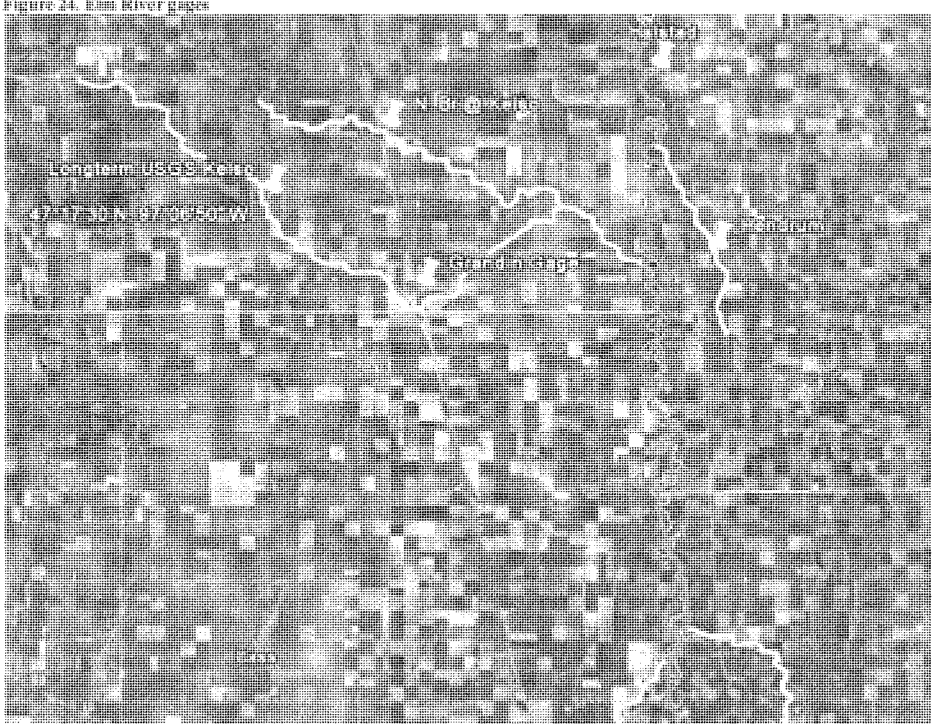


Figure 25. Flow Record Correlation for Elm River at Kelso

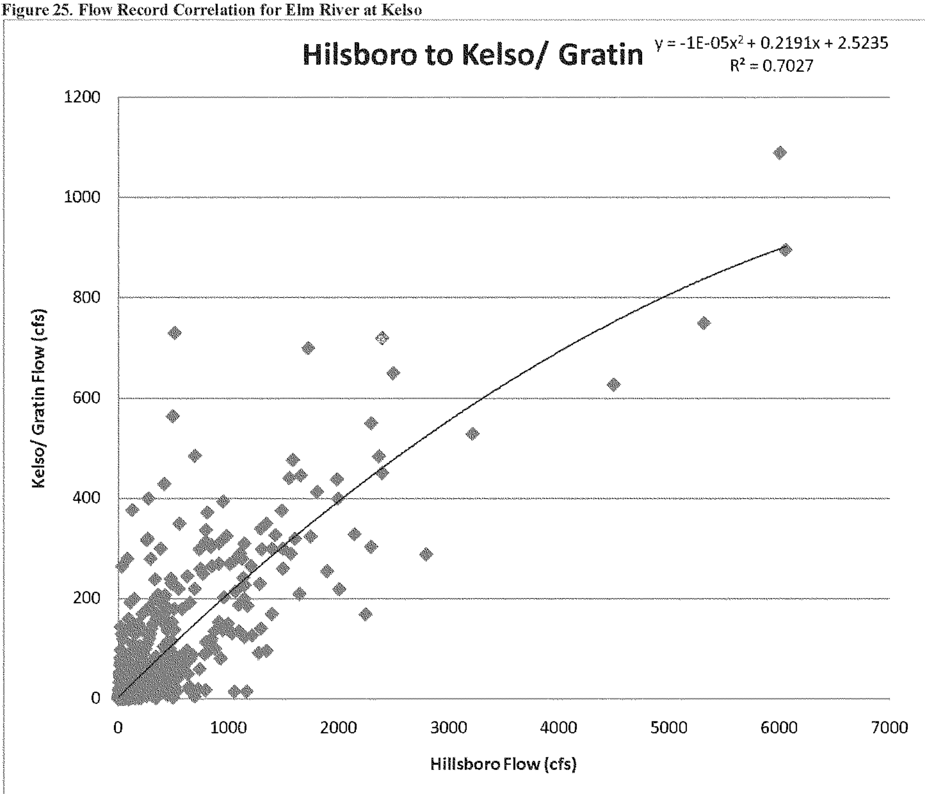


Figure 26. 2006 Event hydrograph comparing the two Mapleton Gages

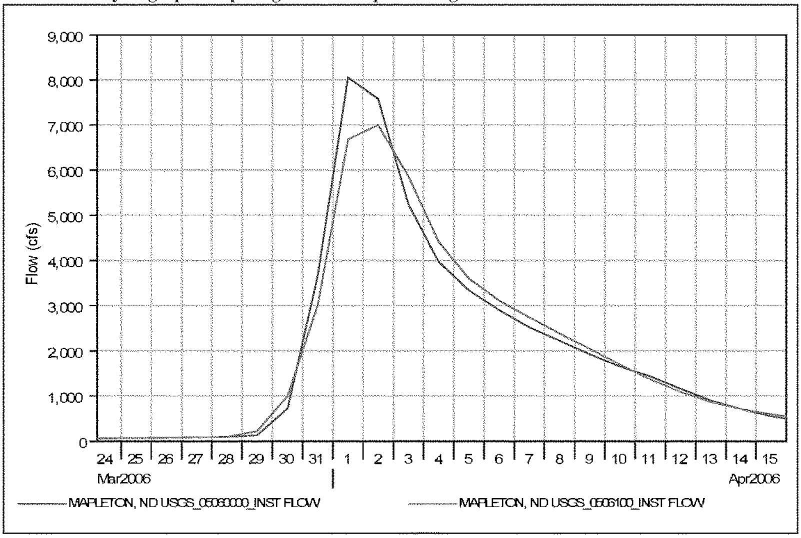


Figure 27. Comparison between Enderlin gage and Mapleton Gage: 1997

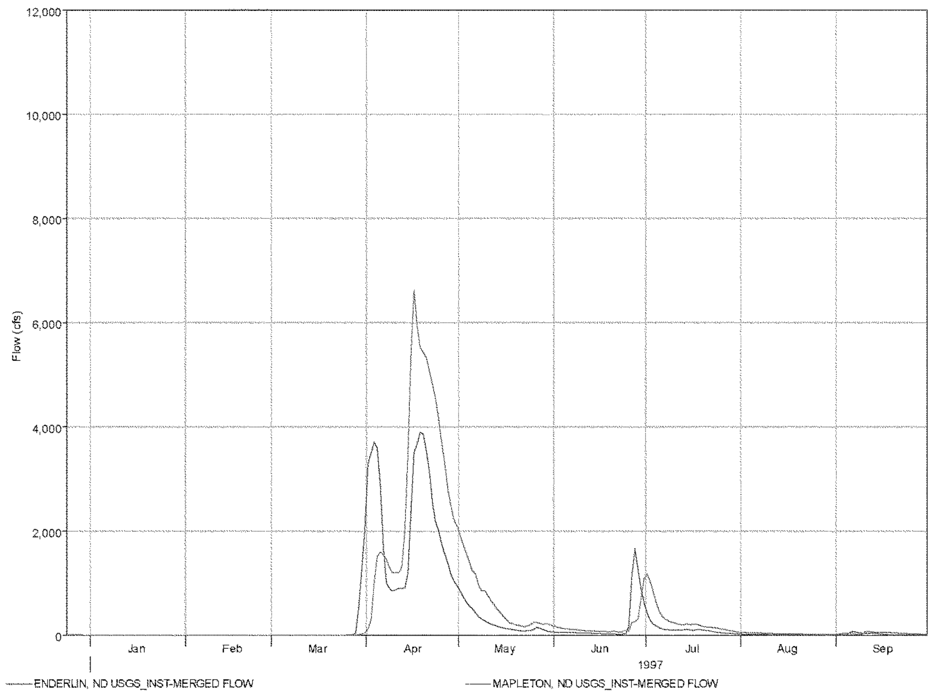


Figure 28. Comparison between Enderlin gage and Mapleton Gage: 2009

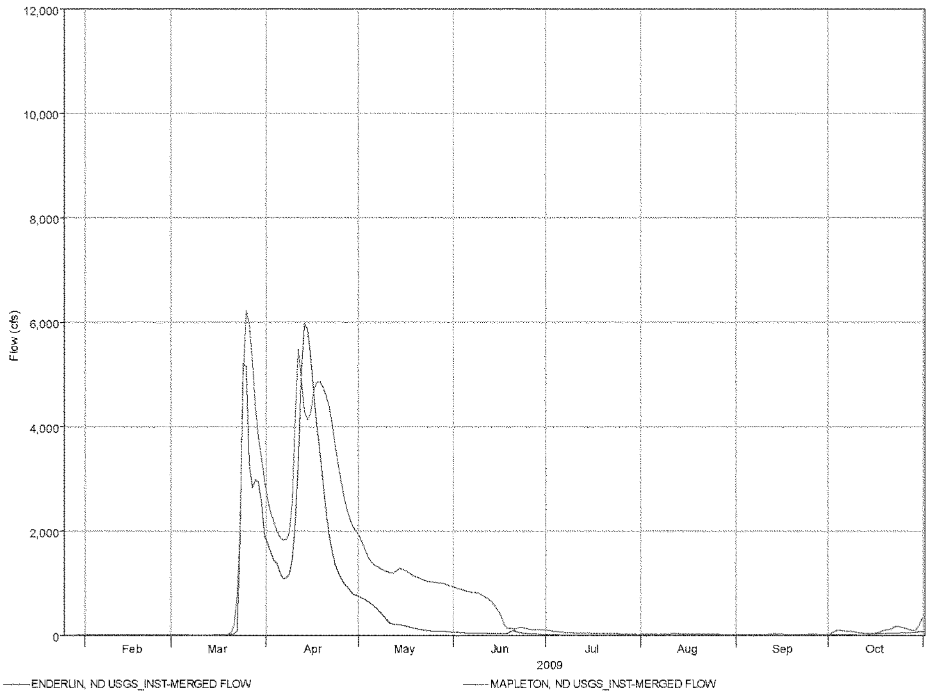


Figure 29. Sheyenne River - Model Calibration at Harwood: 1997

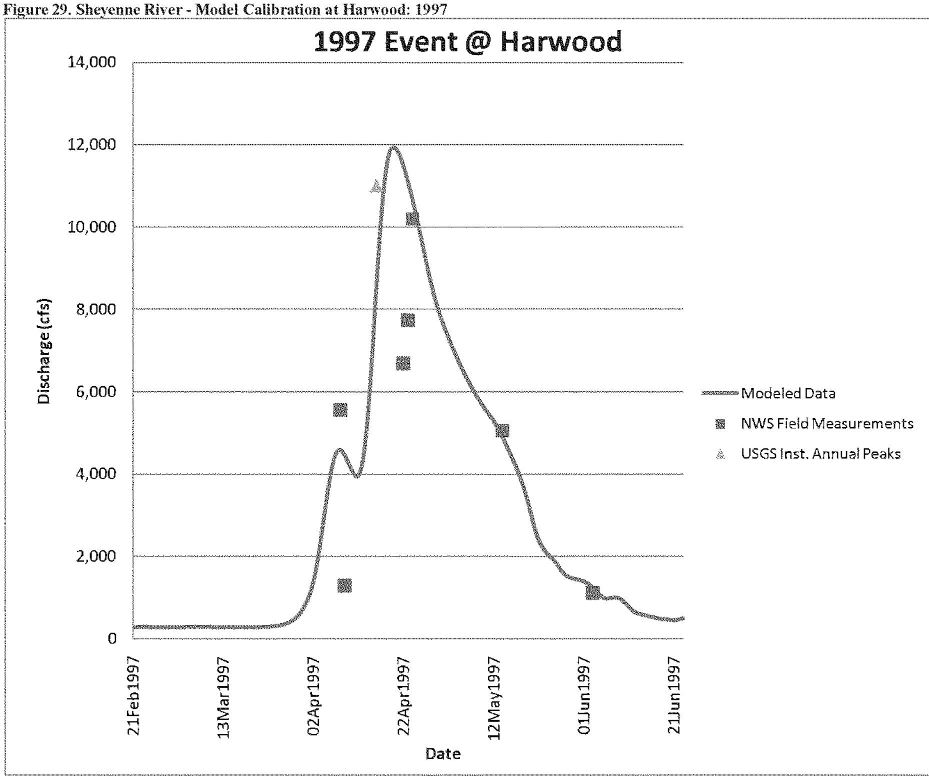


Figure 30. Sheyenne River Model Calibration at Harwood: 2006

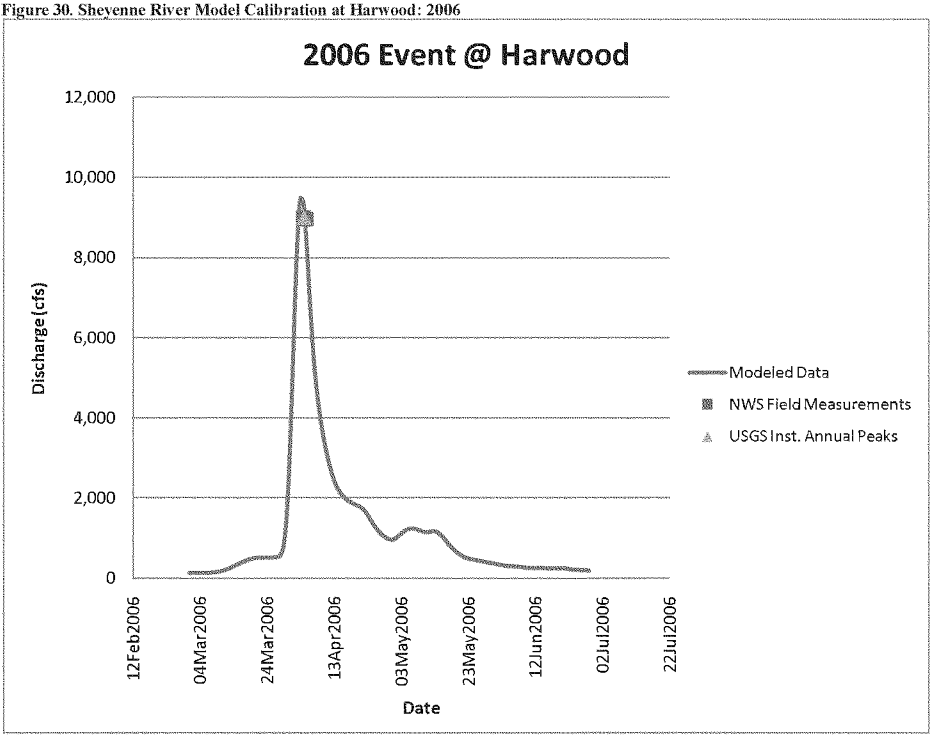


Figure 31. Sheyenne River Model Calibration at Harwood 2009

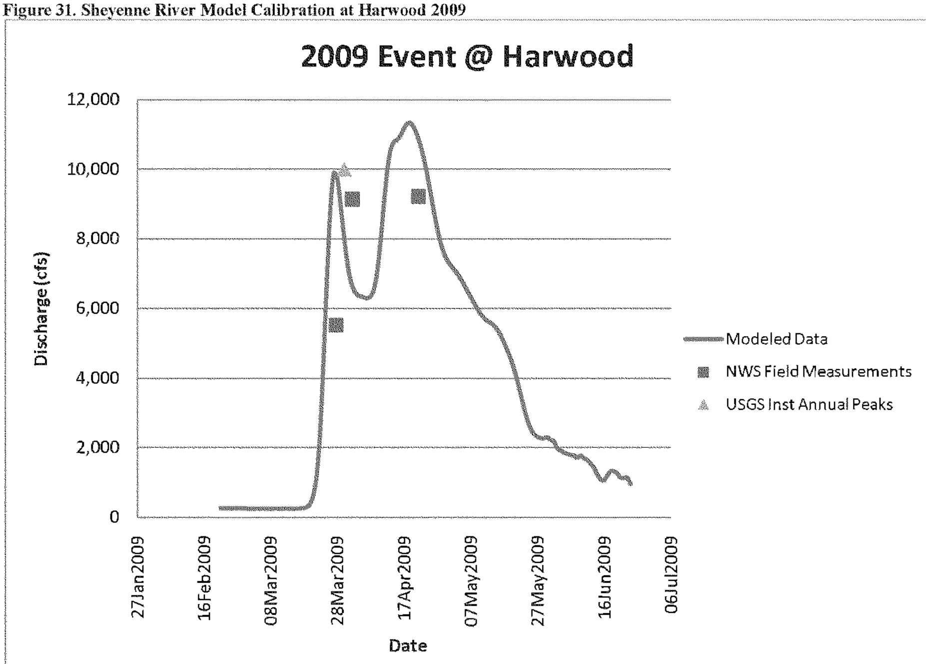


Figure 32. 1997 Event calibration

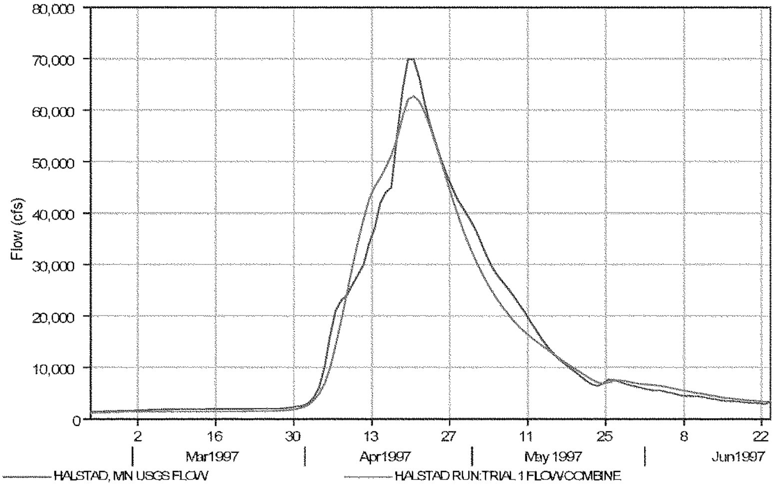


Figure 33. 2006 Event calibration

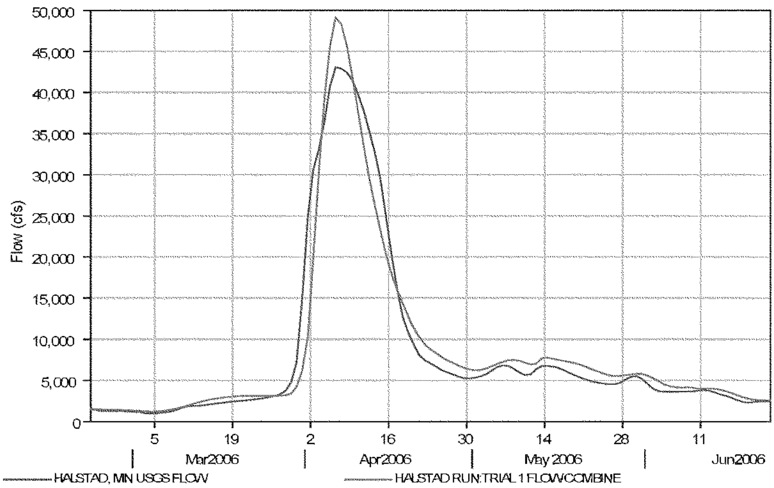
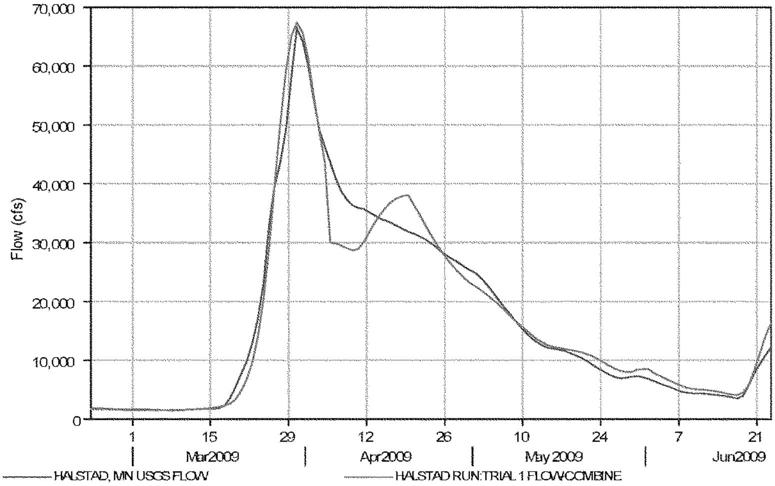


Figure 34. 2009 Event Calibration



Appendix A-4b
Hydrology

Fargo-Moorhead Metropolitan Area Flood Risk Management

Supplemental Draft Feasibility Report and Environmental Impact Statement

April 2011

US Army Corps of Engineers®

Prepared by:
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Preface

As described in the preface to Appendix A-4a, the hydrology associated with the Red River Reach between Fargo and Halstad had to be refined in order to produce improved hydraulic modeling results downstream of Fargo, ND. One of the major study areas that had to be improved upon was the hydrology associated with the Lower Sheyenne River Basin. The Lower Sheyenne River is hydrologically complex due to the effects of regulation, breakout flows and tributary inflow. Additionally, after the downstream impacts of the project, developed in earlier phases of analysis were analyzed, the USACE determined that they were not fully definable and another approach was needed. The USACE and local project sponsors decided to pursue an option that included raising water levels, or staging, upstream of the Fargo-Moorhead Metro area. This proposal would include constructed storage areas as well as natural storage options. To develop a design that incorporates the benefits of upstream storage and staging, an unsteady flow model was required for the study area. The unsteady model requires synthetic balanced hydrographs representative of points of interest in the basin as boundary conditions.

There are two major tributaries to the Lower Sheyenne River: the Maple River and the Rush River. The first section of this Appendix discusses the Maple River. The flows associated with the Maple River are affected by the Maple River Dam. It was necessary to model the Maple River in order to develop a homogenous flow record on the Maple River at Mapleton representative of the current conditions on the Maple River (dam in place). Utilizing this homogenous record, annual instantaneous flow-frequency analysis could be carried out at points of interest along the Maple River in order to produce balanced hydrographs associated with the 0.2-, 0.5-, 1-, 2-, 3-, 4-, and 5-% exceedance frequency events. These balanced hydrographs are utilized as inputs to hydraulic modeling. Similarly, annual instantaneous flow-frequency analysis and subsequent balanced hydrographs were developed for the Rush River. Balanced hydrographs representative of local flow in this portion of the Lower Sheyenne River Basin were also required.

There are three major points of interest along the Sheyenne River between Lisbon and its confluence with the Red River of the North: Gol Bridge, Kindred and West Fargo. These locations are effected by breakout flows and regulatory effects. Annual Instantaneous peak flow-frequency and volume duration curves are developed at each of these locations. Using the results of the flow frequency and volume duration analysis balanced hydrographs can be developed at these locations. The balanced hydrographs are used as input to the Lower Sheyenne River HEC-RAS model as a hydrograph boundary conditions.

While Sections 1-4 of this Appendix focuses on developing balanced hydrographs, to serve as boundary conditions for hydraulic modeling, Section 5 provides analysis used to develop design parameters for the Fargo-Moorhead Metro Project. Section 5 includes a description of how coincidental discharge frequency values and balanced hydrographs are determined for the 0.2-, 1-, 2-, and 10-% exceedance frequency events for locations upstream and downstream of Fargo in order to develop the design for appurtenant structures on the Sheyenne, Maple and Rush River tributaries.

1. Maple River

The Maple River is a tributary of the Sheyenne River. The Maple River flows in a northeastward direction. The confluence of the Maple River with the Sheyenne River is located about 4 miles north of West Fargo, ND. The banks of the Maple River can be described as urban land, agricultural land and open space land. Maple River flooding usually occurs as a result of the spring snowmelt runoff. Floodwaters in the Maple River rise at a slow rate. The duration of Maple River flooding is expected to be within the range of 2-5 days for each notable flood event (source: *Flood Hazard Analysis*).

1.1 GEOMORPHOLOGY

Soils within the Maple River watershed range from medium textured loam and clay loam soils to light textured sandy loam soils with heavy silty clay soils being formed on the lacustrine sediments of glacial Lake Agassiz. At Enderlin, ND the Maple River flows through the Maple Delta deposits and along the north edge of the Sheyenne River Delta. Between Enderlin and the Maple River Dam, the Maple River is deeply entrenched in the Maple Delta and thus no breakout flows are expected to occur.

As the Maple River leaves the Maple River Delta downstream of the Maple River Dam it meanders across a 7-mile wide belt of stratified gravel, sand, silt and clay shore deposits, which were formed on a wave eroded till surface. It continues its meandering course across the nearly level, featureless glacial Lake Agassiz lacustrine plain. This is where breakout flows commonly occur (Source: Flood Hazard Analysis).

1.2 AVAILABLE USGS STREAMFLOW DATA

There are five USGS streamflow gages located on the Maple River:

- USGS Gage 05056100 located Downstream of Mapleton, ND
- USGS gage 05056000 located Upstream of Mapleton, ND
- USGS Gage 05059715 located above the Maple River Dam near Sheldon, ND
- USGS Gage 05059700 located near Enderlin, ND
- USGS gage 05059600 located near Hope, ND.

A map displaying USGS gage locations on the Maple River can be found in **Figure 1.**

The USGS gage near Hope, ND was not utilized in this analysis because it is located near the headwaters of the Maple River and thus its flow record is not representative of the hydrologic characteristics of the river reach between Enderlin and Mapleton. The available USGS daily streamflow data associated with the Enderlin and Mapleton gages is visually described in **Figure 2**.

There are two USGS gages on the Maple River located near the city of Mapleton, ND. The original gage is located downstream of Mapleton. An additional gage was installed upstream of Mapleton in order to avoid recording breakout flows from the Sheyenne River. Breakout flows occur on the mainstem of the Sheyenne River near Kindred, ND and flow into the Maple River just downstream of Mapleton, ND. Currently both gages are functioning at Mapleton. The upstream gage is used primarily during spring flood events. A combination of the two gages is used for this analysis. For the dates when the two gages are functioning concurrently the flow data observed at the upstream gage is utilized.

As can be seen from **Figure 2** there are some gaps in available streamflow data on the Maple River. The Enderlin USGS gage only begins recording flow data in 1957. Neither Mapleton gage is functioning during the period between 1976 and 1994. The portion of the period of record prior to 1957 and 1976-1994 are not used in this analysis. The daily flow record at Mapleton is necessary in order to develop a local flow for the contributing area between Enderlin and Mapleton.

USGS Gage 05059715, located on the Maple River above Maple River Dam near Sheldon, ND, measures discharge and water surface elevation at the dam. The water surface elevation being reported by the gage is the Maple River Dam pool elevation, while the discharge measurements being recorded are the dam's outflow based on the Maple River Dam outflow rating curve. Any flows below 300 cfs are not computed because the Maple River Dam functions as a dry dam. Data is available at this gage for the 2009 Spring Flood Event, the 2010 Spring Flood Event and for two smaller events that occurred during the spring and early summer of 2007.

1.3 DRAINAGE AREAS

The contributing drainage areas associated with the Enderlin and Mapleton gages can be acquired from the USGS. There are 23 square miles of non-contributing area between Enderlin and Mapleton. From **Figure 3,** it is evident that most of the natural storage sites (ponds, small lakes etc.) that make up the non-contributing area are located in the drainage area between Enderlin and the Dam.

Table 1 lists pertinent drainage areas. The drainage areas associated with the reach between the Maple River Dam and Durbin, ND can be estimated using NRCS/USGS Hydrologic Unit Code (HUC) data.

Table 1. Significant Drainage Areas

Gage Location/ Reach	Total D.A (Sq.mi.)	Contributing D.A (Square Miles)	Non-Contributing D.A (Square Miles)
Enderlin USGS Gage	843	796	47
Mapleton USGS Gage	1450	1, 380	70
Enderlin to Mapleton	707	584	23
Maple River Dam	906		
Enderlin to Maple River Dam	63	40	23
Swan Creek		129	
Buffalo Creek		192	
Maple R. Dam to Durbin		205	

1.4 MAPLE RIVER DAM

The construction of the Maple River Dam was authorized by the 1986 Water Resources Development Act, P.L. 99-662. The dam was designed by Moore Engineering. Construction of the Dam began in fall of 2004 and the project was completed in fall of 2006. The Dam consists of a low flow, run of the river, 66" R.C.P.P with a control elevation of 990 NGVD 29, a 125' wide concrete baffle block chute with a control elevation of 1,048 NGVD 29, and a 1,200 food wide earthen emergency spillway with a control elevation of 1, 055 NGVD 29. The Maple River Dam was constructed in order to reduce the depth and duration of flooding along the Maple, Sheyenne, Rush and Red Rivers in eastern North Dakota. An aerial photograph of the dam can be found in **Figure 8**. The Maple River Dam functions as a dry dam.

1.5 MAPLE RIVER DAM

The Maple River model developed for the Fargo Moorhead Metro Feasibility Study extends from USGS gage 05059700 located near Enderlin, ND to USGS gage 05056000 located upstream of Mapleton, ND. The purpose of this model is to analyze the effects of the Maple River Dam on flow in the Red River basin and to develop a means of generating a homogenous flow record at Mapleton. A diagram displaying the HMS schematic used for modeling the Maple River can be found in **Figure 12.**

1.5.1 Routing Parameters

Muskingum-Cunge routing is utilized to model Maple River flow between Enderlin and Mapleton. Eight point cross sections, reach length, and channel slope are obtained from a *Flood Hazard Analyzes of the Maple River* published by the USDA in 1981. The reach lengths used in the model can be found in **Table 2**. Cross sections are displayed in **Figure 4**.

Table 2. Watershed information used for Routing

Gage Location/ Reach	River Mile/ Reach Length (miles)	Source
Enderlin USGS Gage	105.02	USGS
Maple River Dam (MRD)	88.3	Moore Engineering
Enderlin to MRD	16.72	Computed
Mapleton USGS Gage	20.1	USGS
MRD to Mapleton	68.2	USGS

Based on aerial images of the Maple River it was determined that appropriate Manning's "n" values for the Maple River channel is 0.045 and is 0.05 for the flood plain. This is based on the high degree of sinuosity associated with the channel, as well as vegetation and land usage. The floodplain within the Maple River watershed is composed primarily of agricultural land and open space land. Samples of the imagery used to make this determination can be found in **Figure 5 - Figure 7**. This conforms to the Manning's "n" used in the Sheyenne River geomorphology study prepared by West Consultants, Inc for the Corps of Engineers in 2001.

1.5.2 Hydraulic Control Structures: Maple River Dam

The dam's storage capacity was modeled in HEC-HMS using an elevation-storage relationship developed using LIDAR data. This relationship is displayed in **Figure 9**. The outflow from the Dam was modeled as a single specified spillway (as advised by HEC modelers) utilizing an Elevation Discharge Function provided by the USGS. The USGS has made adjustments to the original rating curve for the dam (provided by Moore Engineering) based on field measurements recorded just downstream of the dam. This relationship is displayed in **Figure 10**.

1.5.3 Local Inflow & Breakout flows

1.5.3.1 Breakout flows

Based on conversations with Moore Engineering and their field experience with the Maple River watershed, it can be assumed that during large flood event like the 2009 event breakout flows occur between the Maple River Dam and Mapleton. Much of these breakout flows occur near Durbin, ND and are likely on the order of 1,000-3,000 cfs. These breakout flows re-enter the Sheyenne River prior to its confluence with the Red River of the North. The breakout flows near Durbin,ND drain into Cass County Drain 14 as depicted in **Figure 11.**

In order to accurately model flows at Mapleton these breakout flows were accounted for within the local flow inputs used to calibrate the model. Because these breakout flows re-enter the Sheyenne River system downstream of Mapelton they have to be accounted for when utilizing the model output at Mapleton as an input to any comprehensive model of the Sheyenne River. This can be accomplished by applying a breakout ratio to flow hydrographs being utilized for downstream modeling. This breakout ratio can be determined itteratively using unsteady HEC-RAS modeling.

1.5.3.2 Local Flow Determination

During POR simulations of the Maple River flows were first routed to the Mapleton without inputing a inflow record representing local flow. The resulting flow at Mapleton was subtracted from the USGS gaged record at Mapleton to determine the local inflow record between Enerlin and Mapleton. In order to determine the local flow record between Enderlin and the Maple River Dam a drainage area ratio was applied to the total local flow hydrograph. The drainage area ratio utilized can be found in **Table 3**.

Table 3. Drainage Area Ratio for Local Flow: Enderlin to Maple River Dam

Gage Location/ Reach	Contributing D.A (Square Miles)
Enderlin USGS Gage	796
Mapleton USGS Gage	1, 380
Enderlin to Mapleton	584
Enderlin to Maple R. Dam	40
Drainage Area Ratio	0.07

The local flow hydrograph between Enderlin and Maple River Dam was applied to the model and flows are once again routed from Enderlin to Mapleton and subtracted from the USGS gaged record at Mapleton. The resulting data series is representative of the local flow record between Maple River Dam and Mapleton.

Note that these "local inflows" are representative of not only local flows, but also of the flow lost by the breakout flows known to occur near Durbin, ND.

1.5.4 Model Results

Modeling was carried out in two phases. First, the model was calibrated using USGS gage data and then POR simulations were run in order to develop a homogenous reocord for both the with dam and without dam conditions.

1.5.4.1 Calibration Runs

Calibration runs were carried out utlizing the gaged elevation and discharge record located above Maple River Dam near Sheldon to compare modeled results for the 2009 spring flood event. **Figure 13** and **Figure 14** display the results of model calibration.

1.5.4.2 POR Simulations

The construction of the Maple River Dam has resulted in a lapse in the homogenity of the flow record recorded by the Mapelton, ND USGS gage. In order to produce a homogenous flow record for both the regulated and unregulated conditions at Mapleton is is necessary to utlize a HEC-HMS model to simulate portions of the POR. The POR prior to the construction of the dam from 1957-1975 and 1995-2006 must be simulated with the dam in place. The POR following the construction of the dam, 2006 -2009, must be simulated without the dam in place.

1.5.4.3 Homogenous Flow Records

The results from the Maple River Model Simulations can be found in **Figure 15.** As can be seen in the figure the Maple River Dam has a significant effect on the peak flows being recorded at Mapleton, ND.

Table 4 lists all the annual peaks at Mapleton for the "With Dam" and "Without Dam" conditions. When there was less than a 5% change between the regulated and unregulated flows it can be concluded that the Dam had little effect on reducing flow. This is indicated by the years highlighted in purple. For the majority of years the Maple River Dam significantly reduced the annual peak flow value at Mapleton, ND.

Table 4. Comparison between Homogenous Regulated to Unregulated Flow records at Mapleton, ND

Water Year	*Unregulated Flows*	Regulated Flows	% Reduction in Peak
	Annual Peak Flows (cfs)		
1957	430.0	415.9	
1958	195.0	183.1	6%
1959	1160.0	1,016.00	12%
1960	1220.0	1,128.10	8%
1961	49.0	45.9	6%
1962	2740.0	2,563.10	6%
1963	779.0	728	7%
1964	314.0	284.8	9%
1965	3210.0	2,642.20	18%
1966	3610.0	3,092.60	14%
1967	1420.0	1,332.70	6%
1968	302.0	316.3	
1969	7000.0	5,015.10	28%
1970	3340.0	2,923.80	12%
1971	778.0	733.8	6%
1972	2430.0	2,265.90	7%
1973	1300.0	1,106.60	15%
1974	1970.0	1,840.30	7%
1975	11600.0	8,031.10	31%
1995	2360.0	2182.9	8%
1996	3460.0	1936.1	44%
1997	7150.0	6167.8	14%
1998	4000.0	3284.7	18%
1999	3210.0	2850.4	11%
2000	4110.0	3898.3	5%
2001	6890.0	5921.5	14%
2002	868.0	717.3	17%
2003	751.0	692.5	8%
2004	1450.0	1397.2	
2005	4680.0	4283.4	8%
2006	9900.0	7825.0	21%
2007	2499.5	2460.0	
2008	1917.3	1990.0	
2009	8465.2	6470.0	24%

Key
DS Mapleton USGS Gage
Simulated Flows
Low Outlier
US Mapleton USGS Gage
No Significant Effect

1.6 FREQUENCY ANALYSIS

1.6.1 Maple River Dam Inflow & Outflow

1.6.1.1 Flow-Frequency Curve

Both the inflows into the dam and the outflows from the dam can be simulated for the period of record: 1957-1975, 1995-2009. An annual peak record could be developed from the simulated record. The annual peak inflows could be used to develop an analytical curve representative of flows into the dam. The flow frequency curve representative of inflows into the dam can be found in **Table 5**. This inflow flow-frequency curve is utilized to provide guidance while drawing the outflow frequency curve and is displayed in **Figure 16**. The regional skew value used for the analytical curve is adopted from USGS "Generalized Skew coefficients for Flood Frequency Analysis in Minnesota." The regional skew value (-0.405) at the Enderlin gage can be assumed to be a good estimate of regional skew for inflows into the dam.

Table 5. Maple River Dam- Inflow Frequency Curve

Flow-Frequency Curve	
Maple River Dam Inflows	
% Chance of Exceedance	Flow (cfs)
0.2	15,980
0.5	12,913
1	10,686
2	8,564
5	5,966
10	4,196
20	2,631
50	946
80	284
90	141
95	75
99	21
Statistics	
Mean	2.921
Standard Dev	0.583
Station Skew	-0.776
Regional Skew	-0.405
Weighted Skew	-0.571
Adopted Skew	-0.571
Systematic Events	33

The annual peak outflows from the dam as listed in **Table 6**, plotted using the Weibull plotting position, can be used to develop a graphical flow-frequency curve. As can be seen in **Figure 16** the outflow frequency curve displays regulatory effects between the 2-year event and the 100-year event. It appears that the 10-year event is most affected.

Table 6. Simulated Annual Peak Outflows- Maple River Dam

Maple River Dam-Annual Peak Outflows	
Year	Flow (cfs)
1957	853
1958	145
1960	506
1961	25
1962	690
1963	232
1964	74
1965	930
1966	885
1967	532
1968	305
1969	1,000
1970	687
1971	144
1972	582
1973	624
1974	501
1975	971
1995	865
1996	945
1997	2,534
1998	849
1999	941
2000	642
2001	901
2002	128
2003	382
2004	808
2005	843
2006	905
2007[1]	888
2008[1]	574
2009[1]	5,010
[1]USGS recorded Outflows	

1.6.1.2 Volume-Frequency Analysis

A graphical volume duration frequency analysis could be developed for the outflow of the Maple River Dam. Data is plotted using the Weibull plotting position. Only the daily data for the calendar years between 1957-1975 and 1995-2009 is utilized. The family of curves can be seen in **Figure 16.**

1.6.2 Mapleton

1.6.2.1 Flow-Frequency Curve

The observed flow record, as well as a simulated record for 2007-2009 could be used to develop an analytical curve representative of the unregulated condition at Mapleton. The annual peak flow data for the unregulated condition at Mapleton is displayed in **Table 4.** The regional skew value used for the analytical curve is adopted from USGS "Generalized Skew coefficients for Flood Frequency Analysis in Minnesota." The regional skew value (-0.405) at the Enderlin gage can be assumed to be a good estimate of regional skew for Mapleton gage, as well. The flow-frequency curve for the without dam condition is displayed in **Figure 18**. This analytical flow-frequency curve is utilized to provide guidance when drawing the graphical With Dam flow-frequency curve. The values associated with the Mapleton without Dam Flow Frequency curve are displayed in **Table** 7.

Table 7. Mapleton Without Dam Flow-Frequency Curve

Flow-Frequency Curve	
Mapleton, ND Without Dam	
% Chance of Exceedance	**Flow (cfs)**
	24,297
0.2	19,787
0.5	16,563
1	13,516
2	9,786
5	7,211
10	4,863
20	2,123
50	835
80	492
90	310
95	124
Statistics	
Mean	3.295
Standard Dev	0.458
Station Skew	-0.428
Regional Skew	-0.405
Weighted Skew	-0.416
Adopted Skew	-0.416
Low Outliers	1
Systematic Events	34

The flow record at Mapleton with the dam in place can be simulated for the period of record: 1957-1975 and 1995-2006. An annual mean daily peak record could be developed from the simulated record, along with the observed annual peaks from 2007-2009. The annual mean daily peak flow at Mapleton, plotted using the Weibull plotting position could be used to develop a graphical flow-frequency curve.

It is necessary to adjust the annual mean daily peak flow-frequency curve to be representative of the instantaneous annual peak flow frequency curve. This is done by developing a relationship between mean daily annual peaks and instantaneous annual peaks using the unregulated observed flow record at Mapleton. This relationship can be seen in **Figure 17**. Due to the effects of regulation, the flow hydrographs representative of dam outflows have very gradual peaks (slope ~ 0 near peaks). Thus, it is unnecessary to make this adjustment for the flow-frequency curve representative of outflows.

As can be seen in **Figure 18** the Mapleton frequency curve displays regulatory effects between the 2-year event and the 100-year event. As with the dam outflow curve, it appears that the 10-year event is affected most. The flow-frequency values representative of the regulated condition at Mapleton are also listed in **Table 8**.

Table 8. With Dam at Mapleton- Frequency Curves

	Graphical Flow-Frequency Curve	
	Mean Daily Curve (cfs)	Annual Inst. Curve (cfs)
0.2	24,297	24,297
0.5	19,787	19,787
1	15,000	16,247
2	11,600	12,564
5	7,900	8,556
10	5,800	6,282
20	4,200	4,549

Volume-Frequency Analysis

A graphical volume-frequency curve could be developed for the regulated record at Mapleton. Data is plotted using the Weibull plotting position. Only the daily data for the calendar years between 1957-1975 and 1995-2009 is utilized. The family of curves can be seen in **Figure 19**.

1.7 BALANCED HYDROGRAPHS

A HEC-RAS Unsteady Model is being developed for the Fargo Moorhead Metro Feasibility Study. Hydraulic engineers require synthetic balanced hydrographs representative of the current conditions on the Maple River (dam in place) for the Swan Creek, Buffalo Creek, and at Durbin, ND.

Moore Engineering developed a methodology that has successfully been used to produce these hydrographs using the hydrographs representative of Maple River Dam outflows and Mapleton.

1.7.1 Mapleton & Maple River Dam Outflows

Balanced hydrographs for the 10, 50, 100, 200 and 500 year events are developed at Mapleton and for the outflow from the dam using the volume duration curves described in Section 1.6, the simulated 2006 spring flood event hydrographs and HEC-1.

1.7.2 Durbin, Swan Creek, Buffalo Creek

1.7.2.1 Time Shift

The first step in defining the balanced hydrographs at these locations is to apply a lag time to the balanced hydrograph representative of Dam Outflow. The lag time is representative of the time it takes for flow to travel between the dam and Mapleton, ND. Because this time step is unknown a range of time steps (between 0 and 3 days) was utilized to lag the balanced hydrographs. The HEC-RAS modelers will be able to determine which set of hydrographs works best during the calibration process.

1.7.2.2 Local Flow Hydrograph: Dam to Mapleton

The cumulative local flow hydrograph between the Dam and Mapleton can be determined by finding the difference hydrograph between the dam outflow hydrograph (with the time step applied) and the Mapleton.

1.7.2.3 Breakout flow factor

As the HEC-RAS modelers input the hydrographs into their model they will adjust the hydrographs using a breakout factor. This breakout factor is modified iteratively until the modeled Mapleton balanced hydrograph matches the adopted Mapleton balanced hydrograph developed with HEC-1.

1.7.2.4 Superposition

This methodology assumes that the flow hydrographs representative of Swan Creek, Buffalo Creek and the local area flow between the dam and Durbin have the same shape and timing. Using this assumption the theory of superposition can be applied to the local flow hydrograph representative of the area between the dam and Mapleton to develop three hydrographs representative of Swan Creek, Buffalo Creek and the Dam to Durbin local flow. The cumulative hydrograph is broken down by using drainage area ratios as shown in **Table 9**. By adding the local flow hydrograph between the dam and Durbin to the dam outflow hydrograph you get a balanced hydrograph representative of hydrologic conditions at Durbin, ND.

Table 9. Drainage Area Ratios

Reach	Drainage Area (sq mi)	D.A ratio
Enderlin to Mapleton	526	1
Swan Creek	129	0.25
Buffalo Creek	192	0.36
Local Flow Dam to Durbin	205	0.39

2. Rush River Analysis

The Rush River is a tributary of the Lower Sheyenne River. It lies within the Lake Agassiz Plain. **Figure 20** displays the Rush River watershed.

2.1 AVAILABLE USGS STREAMFLOW DATA

USGS gage 0506500 is located on the Rush River at Amenia, ND. It has a contributing drainage area of 116 square miles. Its period of record is from April 14, 1947 to present. These values are presented in **Table 10**.

Table 10. Annual Instantaneous Peak Flow Record at USGS gage 0506500 on the Rush River at Amenia, ND

Water Year	Annual Instantaneous Peak Flow (cfs)	Water Year	Annual Instantaneous Peak Flow (cfs)
1947	1,230	1982	710
1948	590	1983	438
1949	400	1984	957
1950	620	1985	164
1951	308	1986	757
1952	600	1987	475
1953	1,050	1988	30
1954	120	1989	602
1955	200	1990	64
1956	250	1991	43
1957	115	1992	255
1958	77	1993	2,970
1959	100	1994	470
1960	437	1995	700
1961	25	1996	790
1962	450	1997	1,680
1963	68	1998	1,000
1964	100	1999	1,060
1965	900	2000	1,100
1966	300	2001	1,480
1967	384	2002	457
1968	190	2003	613
1969	1,650	2004	1,070
1970	380	2005	863
1971	97	2006	1,690
1972	252	2007	856
1973	200	2008	357
1974	790	2009	2,000
1975	2,550		
1976	150		
1977	41		
1978	375		
1979	3,650		
1980	63		
1981	22		
1982	710		

2.2 FREQUENCY ANALYSIS

2.2.1 Flow-Frequency Analysis

An analytical flow frequency study is carried out at Amenia using the USGS annual instantaneous peak flow record at Amenia, ND. Weighted skew, using a generalized skew coefficient from the USGS Generalized Skew study, is utilized to carry out analysis. The resulting flow-frequency curve is displayed in **Figure 21** and **Table 11.**

Table 11. Flow-Frequency Curve and Statistics for USGS gage 0506500 Rush River at Amenia, ND

Annual Instantaneous Peak Flow-Frequency Curve			
POR: 1947-2009			
% Chance of Exceedance		**Computed Curve Flow in cfs**	
0.2		6,419	
0.5		5,128	
1		4,215	
2		3,365	
5		2,346	
10		1,664	
20		1,064	
50		411	
80		139	
90		75	
95		43	
99		15	
Statistics			
Mean	2.573	Historic Events	0
Standard Dev	0.53	High Outliers	0
Station Skew	-0.508	Low Outliers	0
Regional Skew*	-0.388	Zero Or Missing	0
Weighted Skew	-0.461	Systematic Events	63
Adopted Skew	-0.461	Historic Period	none

2.2.2 Volume Duration Analysis

HEC-SSP is used to generate a flood volume frequency analysis at Amenia, ND. The USGS mean daily flow record for water years 1947 through 2009 is available for analysis. In order to develop a consistent set of curves for all durations smoothing functions are developed and applied to skew and standard deviations for the family of flood volume curves. Smoothed statistics are anchored by the annual instantaneous flow-frequency statistics displayed in **Table 11**. **Table 12** shows the adopted smoothed statistics for each duration. The flood volume frequency curves identify peak flows for all durations.

Table 12. Flood Volume Frequency Statistics for USGS gage 0506500 Rush River at Amenia, ND

Adopted Statistic	Instant. Peak	1-day	3-day	7-day	15-day	30-day	60-day	90-day	120-day	183-day
Mean Logarithm	2.5734	2.4832	2.3773	2.2102	2.0172	1.8131	1.5822	1.4634	1.3932	1.3806
Pre-adj. stats.										
Standard deviation	0.5301	0.5434	0.5458	0.5474	0.5364	0.511	0.4953	0.4807	0.4587	0.4049
Skew	-0.4612	-0.4883	-0.4625	-0.4594	-0.4876	-0.3601	-0.3146	-0.3222	-0.3902	-0.5555
Adj. stats.										
Standard deviation	0.5301	0.5253	0.5197	0.5109	0.5006	0.4898	0.4776	0.4713	0.4675	0.4658
Skew	-0.4612	-0.4563	-0.4507	-0.4417	-0.4314	-0.4204	-0.4081	-0.4017	-0.3979	-0.3962

2.3 BALANCED HYDROGRAPHS AT AMENIA, ND

The flood volume frequency curves identify peak flows for all durations. The balanced hydrograph feature of HEC-1 is used to configure the balanced hydrographs. HEC-1 is limited to only five durations. The following durations are specified in the HEC-1 input file: 1 (instantaneous peak), 3-, 7-, 15-, and 30-day durations. To be consistent with the methodology adopted throughout the Fargo Moorhead Metro Feasibility Study, the 2006 event as recorded by the USGS gage at Amenia, is used as a pattern hydrograph for configuring the balanced hydrographs. Balanced hydrographs are computed for the 0.5-, 0.2-, 1-, 2-, and 10 % exceedance frequencies. HEC-DSSVue is then used to smooth out the resulting Hec-1 output hydrographs.

3. Balanced Hydrographs for Ungaged Sites

Balanced Hydrographs representative of the local flow between Durbin, ND and the confluence of the Maple River, as well as for the local flow associated with Drain 14 are developed using a drainage area ratio with USGS gage 05060500 Rush River at Amenia, ND.

It is assumed that the hydrographs representative of the local flow that runs into Drain 14 and into the Maple River between Durbin, ND and the Maple River's confluence with the Sheyenne River are similar in shape and timing as the hydrographs at Amenia. Based on this assumption local flow hydrographs can be estimated using drainage area ratios and the balanced hydrographs developed for Amenia. Amenia's drainage area come from the USGS website. Moore Engineering has provided an estimate for the Drain 14 drainage area. The local area between Durbin and the Maple River's confluence with the Sheyenne River can be estimated using HUC data. These areas, along with the drainage area ratios utilized to develop balanced hydrographs are listed in **Table 13.**

Table 13. Drainage Areas and Drainage Area ratios used to get local flows

Location	Drainage Area (sq. miles)
Drain 14 Drainage Area	125.50
Local Area Durbin to Confluence of Maple & Sheyenne Rivers	19.70
Amenia Gage	116
Drain 14 Ratio	1.08
Local Area Flow Ratio	0.17

4. Sheyenne River

There are three major points of interest along the Sheyenne River between Lisbon and its confluence with the Red River of the North: Gol Bridge, Kindred and West Fargo. These locations are effected by breakout flows and regulatory effects. Flow-frequency and volume duration curves are developed at each of these locations. **Table 14** displays the flow-frequency values adopted for each of these locations on the Sheyenne River. Using the results of the flow frequency and volume duration analysis balanced hydrographs can be developed at these locations. The balanced hydrographs are used as input to the Lower Sheyenne River HEC-RAS model as a hydrograph boundary conditions.

Table 14. Annual Peak Discharge-Frequency; Sheyenne River @ GOL, Kindred, & W Fargo

Location Annual Peak	Discharge-Frequency (cfs) % Chance Exceedance				
	10	2	1	0.5	0.2
GOL Bridge	4,190	7,140	8,500	9,900	11,800
Kindred	4,190	5,839	5,910	5,962	5,986
West Fargo	3,800	4,800	4,900	4,950	5,000

4.1 BALDHILL DAM

Sheyenne River flow is regulated to a large degree by Baldhill Dam which creates the impoundment of Lake Ashtabula. USGS gage station 05057500 records outflows from Baldhill Dam. Baldhill Dam began to regulate flows in April of 1950. Previous and current dam regulation is predicated based on the snow water equivalent in the upper portion of the watershed. During major flood events Baldhill Dam stores flow and then releases flow when channel capacity is available or flood storage is consumed. This generally produces a double peak hydrograph on the Lower Sheyenne River. For hydrological analysis at locations downstream of the dam only flows for the period of record from the inception of the dam onward are included in analysis (1950 to 2009).

In the spring of 2004, Baldhill Dam increased its flood control storage capacity by allowing a 5'raise in the top of flood control. This creates a discontinuity in the flows recorded by the USGS gage at Baldhill Dam and at downstream gaging stations.

A reservoir simulation model was developed for the post 5' raise condition and a period of record simulation was carried out down to Kindred. The increase in drainage area of 1,415 square miles between Baldhill Dam and Kindred dampened the effect that the change in regulation had at Kindred resulting in changes in annual peak flow that appeared minimal (less than 5% for the 1997 flood and less than 1 % for smaller events). The flow records at the Kindred gage and downstream can be assumed to be relatively homogenous despite the 2004 change in flood control operation at Baldhill Dam. Thus, for this analysis no adjustments were made to the peak flows recorded between 1950 and 2004 to render the POR homogeneous.

4.2 SHEYENNE RIVER NEAR KINDRED, ND

Significant break outflows occur on the Sheyenne River upstream and downstream of USGS gage 05059000 located at Kindred, ND. The breakout flows that flow out of the Sheyenne River near Kindred occur to the southeast toward the Wild Rice River, ND and to the north towards Drain 34 and 14. Drains 34 and 14 drain into the Maple River above the Maple River's confluence with the Sheyenne River.

The flow record at Kindred has a period of record of 1947, 1950 to 2009. The drainage area at the Kindred gage, according to the USGS, is 8,880 square miles. At least 5,780 square miles is non-contributing area. The non-contributing area includes 3,800 square miles from the Devils Lake Basin. Intervening area between Kindred and Baldhill Dam is approximately 1,415 square miles.

4.2.1 GOL Bridge

Gol Bridge is located upstream of the break flows that occur from the Sheyenne River between Lisbon and Kindred, ND. Flows at Gol Bridge are representative of the total flow translated downstream from Baldhill Dam before breakouts occur.

4.2.1.1 Flow-Frequency Analysis

There is not a continuous annual instantaneous peak streamflow record available for Gol Bridge, ND. Because Gol Bridge is located relatively close to Kindred, ND the annual instantaneous peaks at Kindred, ND can be assumed to be equivalent to the streamflow record at Gol Bridge for the portions of the POR when no breakouts occurred. For those years when breakouts are known to have occurred upstream of Kindred the annual peak flows at the Kindred gage can be adjusted using a breakout flow relationship. This relationship has been developed based on a combination of flow measurements and hydraulic modeling using HEC-RAS. **Figure 22** displays the breakout relationship between Gol Bridge and Kindred. This relationship is based on the data displayed in **Table 15**.

Table 15 Upstream Breakout – Gol Bridge to Kindred

Unsteady HEC RAS Model Results							
	Gol Bridge	Left Breakouts	Right Breakouts	Total	Left	Right	Gol Breakout
Old 10-Year	3,456	0	0	0	0%	0%	3,456
Old 50-Year	5,768	207	13	220	94%	6%	5,548
Old 100-Year	7,342	788	788	1,576	50%	50%	5,766
March-April 2009 modeled based on NWS forecast hydrographs	8,950	1,179	1,924	3,103	38%	62%	5,847
Old 500-Year	1,1929	1,963	4,030	5,993	33%	67%	5,936
Actual 2009 based on Gage Records and Measurements				**Kindred**			
2009 based Gage records and Measurements	8,700			5,770	2,930		
	Measurement 4/23/09			Mean Daily 4/23/09			

Using the data displayed in **Table 15** and the breakout relationship displayed in **Figure 22,** a rating curve could be developed and inputted into HEC-DSSVUE in order to back translate peak flows from Kindred to Gol Bridge. **Table 16** lists the rating curve values used in DSSVUE to translate peak flows from Kindred to Gol Bridge. Annual peak flows at Gol Bridge are shown in **Table 17**.

Table 16. Breakout Rating Curve-Gol Bridge to Kindred

Gol Bridge cfs	Kindred cfs
0	0
5,200	5,200
5,500	5,400
6,000	5,650
6,500	5,770
7,000	5,825
7,500	5,875

Table 17. Annual Peak Discharges – GOL Bridge

RANK	WATER YEAR	DISCHARGE CFS	RANK	WATER YEAR	DISCHARGE CFS
1	1997	10,360	31	1972	1,530
2	2009	8,720	32	1956	1,460
3	1996	5,100	33	1967	1,460
4	1969	4,690	34	1989	1,430
5	1975	4,640	35	1978	1,410
6	1979	4,160	36	1992	1,400
7	1995	3,970	37	1970	1,230
8	1993	3,550	38	1955	1,120
9	1966	3,380	39	1968	1,010
10	2001	3,310	40	1951	1,010
11	1950	3,210	41	1976	925
12	2004	3,080	42	2003	760
13	1987	3,000	43	1980	750
14	1999	2,840	44	1973	710
15	1965	2,760	45	2008	695
16	2006	2,600	46	1953	679
17	1962	2,310	47	1954	631
18	1952	2,240	48	1964	600
19	2007	2,160	49	1977	570
20	1983	2,060	50	1985	555
21	1982	2,040	51	2002	549
22	1994	2,030	52	1957	547
23	1998	2,000	53	1958	480
24	2000	1,960	54	1988	460
25	1974	1,940	55	1981	435
26	2005	1,870	56	1963	430
27	1960	1,820	57	1961	350
28	1984	1,810	58	1990	286
29	1971	1,750	59	1959	204
30	1986	1,740	60	1991	184

Utilizing the adopted annual peak discharge record displayed in **Table 17**, a graphical flow-frequency curve could be developed for Gol Bridge. The flow-frequency curve at Gol Bridge is plotted alongside the flow-frequency curve at Kindred in **Figure 23**. The peak flows at Gol Bridge appear to be log-normally distributed. A Bulletin 17B can be applied to the data to develop the flow-frequency curve. **Table 14** lists the synthetic discharge values for the 0.2-, 1-, 2, and 10-% exceedance frequency events.

4.2.1.2 Flood Volume Frequency

HEC-SSP is used to generate flood volume frequency relationships for subsequent development of balanced hydrographs at GOL Bridge. This analysis is conducted using mean daily flows recorded by the USGS gage at Kindred from 1950 to 2009. The period of record mean daily flows at Kindred are "reverse routed" through the breakout transform in **Table 16** for the reach just above Kindred. The resulting mean daily flow series is considered to be representative of the flow record at Gol Bridge and is log-normally distributed and therefore amenable to Bulletin

17B procedures. Skew and standard deviations are smoothed to generate a consistent set of curves for all durations. Skew and standard deviation for the curves are anchored using the statistics associated with the annual instantaneous peak discharge-frequency curve determined by Bulletin 17B analysis. **Table 18** shows the adopted smoothed statistics for each duration.

Table 18. Flood Volume Frequency Statistics - GOL

Adopted Statistics	Instant. Peak	1-day	3-day	7-day	15-day	30-day	60-day	90-day	120-day	180-day
Mean Logarithm	3.1473	3.1300	3.1100	3.0690	3.0030	2.9090	2.7730	2.6890	2.6290	2.5130
Pre-adj. stats.										
Standard deviation	0.3854	0.3870	0.3990	0.4130	0.4290	0.4360	0.4230	0.4070	0.3870	0.3670
Skew	-0.4000	-0.3800	-0.4040	-0.4590	-0.3720	-0.2140	-0.1180	-0.1060	-0.1000	-0.0730
Adj. stats.										
Standard deviation	0.3854	0.3855	0.3862	0.3875	0.3895	0.3924	0.3966	0.3992	0.4011	0.4047
Skew	-0.4000	-0.3974	-0.3854	-0.3601	-0.3196	-0.2638	-0.1819	-0.1314	-0.0967	-0.0260

4.2.1.3 Balanced Hydrograph

The flood volume frequency curves identify peak flows for all durations. The balanced hydrograph feature of HEC-1 is used to configure the balanced hydrographs. HEC-1 is limited to only five durations. The following durations are specified in the HEC-1 input file: 1 (instantaneous peak), 3-, 7-, 15-, and 30-day durations. The 2006 event is used as a pattern hydrograph for configuring the balanced hydrographs. Balanced hydrographs are computed for the 0.5-, 0.2-, 1-, 2-, and 10 % exceedance frequencies. HEC-DSSVue is then used to smooth out the resulting Hec-1 output hydrographs. The balanced hydrograph was used as input to the Lower Sheyenne River HEC-RAS model as a hydrograph boundary condition.

4.2.2 Kindred

4.2.2.1 Flow-Frequency Analysis

Kindred, ND is located downstream of the first reach of the Sheyenne River known to exhibit breakout flows during flood events. In order to correctly represent the breakout flows know to occur during large events, the annual peak discharge-frequency curve at Kindred, ND is determined by translating the values from the flow frequency curve developed at Gol Bridge through the breakout transform displayed in **Table 16**. This was done for the 0.2-, 0.5-, 1-, 2-, 3-, 4-, and 5-% exceedance frequency events displayed in **Table 14**. Because of the effect of the breakout flows just upstream, this curve was drawn graphically. **Figure 23** shows the Kindred curve with the GOL discharge-frequency curve. The curves are identical for flows below 5,000 cfs (~6 % exceedance frequency) because no significant breakout flows occur until channel flow exceeds this value.

4.2.2.2 Balanced Hydrograph

The balanced hydrograph for the Sheyenne River at Kindred is computed within the Lower Sheyenne River HEC-RAS unsteady flow model by routing the input boundary condition hydrograph, determined upstream at GOL Bridge, through the breakout flow relationship.

4.2.3 West Fargo

4.2.3.1 Flow-Frequency Analysis

The annual discharge-frequency curve for West Fargo is based on recorded instantaneous peak discharges at USGS gage station 05059500. The POR for the USGS at West Fargo is from 1903 to present. West Fargo is downstream of Baldhill Dam. Construction of Baldhill Dam was only completed in 1950. To maintain homogeneity, only the West Fargo flow record from 1950 to present is adopted for analysis. Flows recorded by USGS gage 05059500 are representative of flow through the West Fargo Diversion, the Horace diversion and flow through the natural channel. The flow frequency curve at West Fargo has to be developed graphically due to the breakout flows know to occur between Kindred, ND and West Fargo, ND. The breakout flows above Kindred cap the peak flow downstream at West Fargo at approximately 5,000 cfs. This information provides a guide for the upper end of the graphically drawn curve. **Figure 24** shows the West Fargo flow-frequency curve. **Table 14** lists the synthetic discharge values for the 0.2-, 1-, 2-, and 10-% exceedance frequency events.

4.2.3.2 Flood Volume Frequency

Flood Volume Frequency Analysis is conducted at West Fargo using the mean daily flow record for the regulated portion of the period of record from 1950 to 2009. Because flows break out from the Sheyenne River upstream of West Fargo, a graphical volume-frequency analysis must be carried out. HEC-SSP is used to generate the Weibull plotting positions for the flow-volume frequency analysis. Graphical flood volume frequency curves are drawn through the plotting positions using the adopted instantaneous peak curve as a guide. As described for the flow-frequency analysis, the breakout flow above Kindred caps the peak flow downstream at West Fargo at approximately 5,000 cfs. As a result, the flood volume curves converge to 5,000 cfs at the upper end. **Figure 25** displays the flood volume curves for the 1-, 3-, 7-, 15-, and 30-day durations. The adopted instantaneous peak discharge-frequency curve is plotted in red. **Table 19** displays the estimated discharges for each duration and frequency from the discharge volume-frequency curve.

Table 19. Estimated Discharge Volume Duration Frequencies; Sheyenne River @ West Fargo

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.5 %	5,000	4,925	4,850	4,775	4,700	4,625
0.2 %	4,950	4,875	4,790	4,716	4,630	4,550
1 %	4,900	4,815	4,730	4,645	4,560	4,475
2 %	4,800	4,650	4,500	4,350	4,200	4,050
10 %	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

4.2.3.3 Balanced Hydrograph

The flood volume frequency curves identify peak flows for all durations. The balanced hydrograph feature of HEC-1 is used to configure the balanced hydrographs. HEC-1 is limited to only five durations. The following durations are specified in the HEC-1 input file: 1 (instantaneous peak), 3-, 7-, 15-, and 30-day durations. The 2006 event is used as a pattern hydrograph for configuring the balanced hydrographs. Balanced hydrographs are computed for the 0.5-, 0.2-, 1-, 2-, and 10 % exceedance frequencies. HEC-DSSVue is then used to smooth out the resulting Hec-1 output hydrographs. The balanced hydrograph was used as input to the Lower Sheyenne River HEC-RAS model as a hydrograph boundary condition.

5. Mainstem Analysis

5.1 COINCIDENT PEAK ANALYSIS- UPSTREAM

Coincidental discharge frequency values and balanced hydrographs are determined for the 500-, 100-, 50, and 10-yr events for locations on the Wild Rice, ND at Abercrombie, the Red River at Hickson and the Red River just downstream of the Wild Rice, ND when peak flows are occurring at upstream locations. The coincidental annual flow values at Abercrombie and Hickson are determined by identifying on what date the annual instantaneous peak flows occur at the upstream locations and then determining the corresponding flow for that date at Abercrombie, Hickson and just downstream of the Wild Rice, ND. The resulting coincidental annual flows at Abercrombie, Hickson and the Wild Rice River, ND are plotted using the Weibull plotting position and a graphical curve is then drawn to fit the plotting positions. Flow Frequency Curves are displayed in **Figure 26** through **Figure 34**. The period of record used for analysis is displayed on each figure.

5.1.1 Abercrombie & Hickson

Coincidental discharge frequency values and balanced hydrographs are determined for the 500-, 100-, 50-, and 10-yr events at locations on the Wild Rice, ND at Abercrombie and the Red River at Hickson when peak flows are occurring on the Sheyenne River at the following reference points: Gol Bridge, Maple River at Mapleton and the Rush River at Amenia. The coincidental flow records are listed in **Table 20**.

Table 20. Coincidental peak flow records at Abercrombie & Hickson for corresponding Annual peak flows observed in the Sheyenne River Basin

Water Year	Coincidental Peaks at Abercombie, ND on the WRR-ND			Coincidental Peaks at Hickson, ND on the RRN-ND		
	Locations of Annual Peak			Locations of Annual Peak		
	Gol Bridge	Mapleton	Amenia	Gol Bridge	Mapleton	Amenia
1947			2,080			5,718
1948			680			1,728
1949			350			1,024
1950	766		1,550	4,416		3,014
1951	74		8	2,101		351
1952	2,450		4	1,411		748
1953	123		639	2,270		1,360
1954	41		43	1,009		816
1955	21		430	562		359
1956	32		630	943		1,280
1957	80	16	95	670		1,664
1958	25	152	135	605		434
1959	8	29	5	1,006		743
1960	206	549	620	531		1,072
1961	19	23	25	416		333
1962	2,980	2	2	5,460		576
1963	126	191	170	769		736
1964	22	339	119	509		627
1965	511	2,500	2,500	2,357		3,799
1966	880	2,320	1,140	1,626		1,805
1967	574	896	406	1,981		1,624
1968	40	29	14	866		740
1969	6,310	9,360	7,520	9,540		3,690
1970	154	59	160	932		179
1971	21	135	50	539		768
1972	2,050	1,710	395	2,355		2,330
1973	118	353	279	1,059		1,398
1974	48	556	512	789		940
1975	2,740	2,860	2,540	4,857		2,048
1976	171		800	740		1,264
1977	14		3	39		24
1978	2,100		4,400	2,862		3,518
1979	600		4,400	2,188		8,731
1980	875		1,500	3,583		2,634
1981	18		0	255		160
1982	272		1,120	1,240		4,000
1983	244		0	812		294

Table 20. Continued.

Water Year	Coincidental Peaks at Abercrombie, ND on the WRR-ND			Coincidental Peaks at Hickson, ND on the RRN-ND		
	Locations of Annual Peak			Locations of Annual Peak		
	Gol Bridge	Mapleton	Amenia	Gol Bridge	Mapleton	Amenia
1984	344		2,950	1,706		3,898
1985	698		698	1,990		1,990
1986	514		26	3,236		2,060
1987	617		61	2,392		934
1988	6		33	406		684
1989	2,600		1,190	3,727		2,887
1990	2		2	617		610
1991	0		0	805		798
1992	28		149	806		451
1993	555		818	2,593		2,555
1994	1,150		30	3,340		1,373
1995	481	3,680	500	2,233	4,814	1,646
1996	432	2,000	2,000	2,123	4,378	4,378
1997	3,590	9,450	9,050	9,218	6,657	8,284
1998	350	1,500	1,300	1,628	4,540	3,320
1999	740	748	1,530	1,490	1,680	2,600
2000	106	139	130	951	1,439	1,887
2001	9,020	7,590	7,590	8,995	5,026	5,026
2002	91	15	356	1,332	668	922
2003	176	1,770	1,630	1,040	4,040	2,730
2004	28	163	270	512	1,440	785
2005	1,030	1,620	1,030	6,116	6,564	6,116
2006	8,370	8,660	8,660	13,774	8,813	8,813
2007	2,660	3,360	3,360	2,978	3,394	3,394
2008	877	938	45	3,140	3,110	446
2009	5,300	14,000	11,900	6,722	20,166	15,310

Coincidental peaks at Abercrombie are also determined for when the Red River at the North is peaking at Fargo, ND which is just downstream of the Wild Rice River's confluence with the Red River of the North. The coincidental flow record can be found in Appendix A-1. Coincidental peaks at Hickson are also determined for when the Wild Rice River, ND peaks at Abercrombie. The coincidental flow record at Hickson is displayed in **Table 21**.

Table 21. Coincidental peaks at Hickson when Annual Peaks are Occurring on the Wild Rice River-ND at Abercombie, ND

Water Year	Coincidental Flow (cfs)	Water Year	Coincidental Flow (cfs)
1942	4,045	1976	1,264
1943	4,333	1977	339
1944	2,847	1978	4,826
1945	4,796	1979	5,730
1946	3,058	1980	2,834
1947	4,870	1981	284
1948	1,728	1982	1,350
1949	1,380	1983	821
1950	4,678	1984	3,898
1951	2,945	1985	3,000
1952	7,621	1986	3,035
1953	1,047	1987	2,324
1954	662	1988	413
1955	474	1989	11,735
1956	1,114	1990	317
1957	422	1991	2,800
1958	776	1992	1,149
1959	739	1993	4,472
1960	1,072	1994	1,306
1961	303	1995	4,814
1962	5,385	1996	5,215
1963	4,918	1997	8,657
1964	1,131	1998	3,450
1965	5,255	1999	2,700
1966	5,562	2000	1,605
1967	3,169	2001	8,083
1968	711	2002	3,121
1969	7,885	2003	4,250
1970	916	2004	2,720
1971	559	2005	5,110
1972	1,440	2006	12,240
1973	1,483	2007	8,187
1974	943	2008	2,920
1975	4,446	2009	20,106

These flows are necessary to develop the design for appurtenant structures on the Sheyenne, Maple and Rush River tributaries. **Table 22** and **Table 23** show the coincidental discharges that occur at Abercrombie and Hickson respectively, to peak flows at upstream locations.

Table 22. Coincidental Peaks @ Abercrombie

Location Annual Peak	Coincident Discharge at Abercrombie (cfs) % Chance Exceedance			
	10	2	1	.2
GOL	3,700	9,400	10,300	13,000
Mapleton	8,000	15,500	18,000	23,000
Amenia	4,500	12,000	15,000	19,000
Red Confluence	6,185	11,655	13,780	18,342

Table 23. Coincidental Peaks @ Hickson

Location Annual Peak	Coincident Discharge at Hickson (cfs) % Chance Exceedance			
	10	2	1	.2
GOL	6,100	13,400	17,000	28,000
Mapleton	7,200	13,000	15,500	21,000
Amenia	8,200	12,000	15,000	24,000
Abercrombie	6,600	16,000	21,500	37,000

5.1.2 Just Downstream of the WRR-ND

Coincidental discharge frequency values and balanced hydrographs are determined for the 500-, 100-, 50, and 10-yr events at a location on the Red River of the North just downstream of its confluence with the Wild Rice River-ND with the annual peak occurring at the mouth of the Wild Rice River-ND are displayed in **Table 24.**

Table 24. Coincidental Peaks @ Red River Downstream of Mouth of Wild Rice River- ND

Location Annual Peak	Coincident Discharge at RRN DS WRR-ND (cfs) % Chance Exceedance			
	10	2	1	.2
Wild Rice, ND Mouth	16,000	27,000	32,000	42,000

5.2 COINCIDENT PEAK ANALYSIS- DOWNSTREAM

Coincidental discharge frequency values and balanced hydrographs are determined for the 500-, 100-, 50, and 10-yr events at a location on the Red River of the North just downstream of its confluence with the Sheyenne River when peak flows are occurring on the Sheyenne River at the following reference points: Gol Bridge, Maple River at Mapleton and the Rush River at Amenia. The coincidental flow records are displayed in **Table 25**.

Table 25. Coincidental peak flow record on the Red River DS Sheyenne River Confluence

Water Year	Coincidental Peaks on the Red River DS Sheyenne River		
	Locations of Annual Peak		
	Gol Bridge	Mapleton	Amenia
1962	9,245	5,896	4,489
1963	2,894	1,206	2,888
1964	878	4,858	804
1965	13,265	13,266	16,414
1966	11,188	17,420	14,672
1967	8,107	3,712	5,641
1968	1,568	965	1,018
1969	23,516	22,914	20,568
1970	4,683	1,956	6,901
1971	1,286	2,010	2,352
1972	10,384	10,452	625
1973	2,318	750	4,100
1974	6,023	5,521	9,781
1975	26,598	25,728	16,146
1976	1,829		4,797
1977	454		295
1978	6,030		19,161
1979	7,102		27,803
1980	6,767		4,897
1981	626		504
1982	5,829		8,777
1983	3,618		2,861
1984	4,482		14,404
1985	4,690		4,690
1986	7,705		2,539
1987	6,378		4,000
1988	1,420		2,439
1989	14,739		12,729
1990	925		1,159
1991	925		938
1992	1,876		2,626
1993	8,977		11,121
1994	7,571		2,345
1995	6,767	10,921	9,044
1996	5,608	10,184	13,399
1997	26,062	33,634	42,878
1998	4,020	4,958	11,054
1999	8,040	6,834	10,049

Table 25. Continued.

[illegible]	[illegible]		
	[illegible]		
	[illegible]	[illegible]	[illegible]
[illegible]	8,312	14,338	18,882
[illegible]	25,191	25,125	24,521
[illegible]	1,903	3,138	9,580
[illegible]	2,104	2,807	7,908
[illegible]	3,088	2,392	3,643
[illegible]	14,138	3,203	14,138
[illegible]	28,507	28,685	24,521
[illegible]	10,049	6,700	16,012
[illegible]	6,767	3,878	4,571
[illegible]	21,975	32,864	29,143

Determination of these flows assisted design for appurtenant structures on these tributaries. The results of the flow-frequency analysis are displayed in **Table 26.**

Table 26 Coincidental Peaks @ Red DS Shey Confluence when Annual Peak Occurring @:

Location Annual Peak	[illegible]			
	10	2	1	.2
GOL	19,500	32,000	38,000	50,000
Mapleton	31,500	52,000	60,000	80,000
Amenia	21,000	38,000	46,000	64,000
When Mapleton Pk Arrives at Red	27,000	40,000	44,000	50,000

The Red River coincident flows just downstream of the mouth of the Sheyenne River can be estimated using the daily flow record recorded on the Red River at Halstad. The1988 Corps *Timing Study* indicates that there is a travel time of 3 days between the mouth of the Sheyenne River and Halstad. Because local area flow occurs between the mouth of the Sheyenne River and Halstad, flows recorded at Halstad are greater than what would be observed at the mouth of the Sheyenne River. A drainage area ratio can be utilized to determine the relationship between the flow magnitudes observed at the mouth of the Sheyenne River versus those observed at Halstad. Based on drainage area the flows at the Sheyenne River are 33% less than those flows recorded downstream at Halstad and need to be reduced by a ratio of 0.67.

In order to find the coincident annual flow records at the mouth of the Sheyenne River with annual peaks at Gol, Mapleton and Amenia, the dates of the annual peaks at these upstream locations are first identified. The Halstad daily flow record is then shifted back three days and reduced by a ratio of 0.67 to form an equivalent daily flow record just downstream of the mouth of the Sheyenne River. Using this equivalent flow record the flows that occur on the same day as the annual peaks at the upstream locations are determined.

In order to find the coincident annual flow record on the Red just downstream of the mouth of the Sheyenne River with when the peak at Mapleton reaches the mouth of the Sheyenne River, it is first necessary to determine the travel time between Mapleton and the mouth of the Sheyenne River. Travel time is estimated to be five days. The Mapleton annual instantaneous peak record is shifted forward in time five days to account for travel time from Mapleton to form an equivalent flow record at the confluence of the Sheyenne with the Red. The Halstad daily flow record is then shifted back three days and reduced by a ratio of 0.67 to form an equivalent daily flow record just downstream of the mouth of the Sheyenne River. Using this equivalent flow record just downstream of the Sheyenne on the Red, the annual instantaneous peak flows that occur on the same day as when the annual peaks that occurred at Mapleton reach the mouth of the Sheyenne River.

Figure 36 through **Figure 39** display the adopted, coincident discharge-frequency curves.

5.3 ANNUAL INSTANTANEOUS FLOW-FREQUENCY ANALYSIS @ ABERCROMBIE

Annual peak discharge – frequencies were determined for the Wild Rice River, ND at Abercrombie. These flows are compared with the coincident flows and provide more guidance in design of the appurtenant structures as well as an upper bound for the coincident discharge-frequencies. The period of record adopted at Abercrombie is for the WET portion of record 1942 to 2009. The frequency curve is derived analytically utilizing a weighted skew value. Skew is weighted using a regional skew of -0.230 and associated mean square error of 0.125 provided by the USGS Minnesota regional skew study. The adopted flows are listed in **Table 27**. **Figure 35** displays the analytical flow-frequency curve with corresponding statistics.

Table 27 Adopted Annual Peak for Wild Rice River, ND @ Abercrombie

Location	Discharge-Frequency (cfs) % Chance Exceedance			
Annual Peak	10	2	1	.2
Abercrombie	6,415	13,716	17,538	27,863

5.4 5-YR BALANCED HYDROGRAPHS

To refine the environmental assessment of staging water upstream 20% chance of exceedance balanced hydrographs were developed based on the 20% annual instantaneous peak flow value determined for the Red River of the North at Hickson, ND, Fargo, ND, and Halstad, MN and the Wild Rice River-ND at Abercombie, ND.

20% coincidental balanced hydrographs were determined for the coincidental peak on the Red River at Hickson when the Wild Rice River is peaking at Abercombie, ND and for the coincidental peak on the Wild Rice River-ND when the Red River is peaking at Fargo, ND.

6. REFERENCES

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14. West Consultants Inc. 2001. Sheyenne River: Geomorphology Study.

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Figures

Figure 1. Maple River Watershed- USGS Gages (source: Bengtson, M. & G. Padmanabhan)

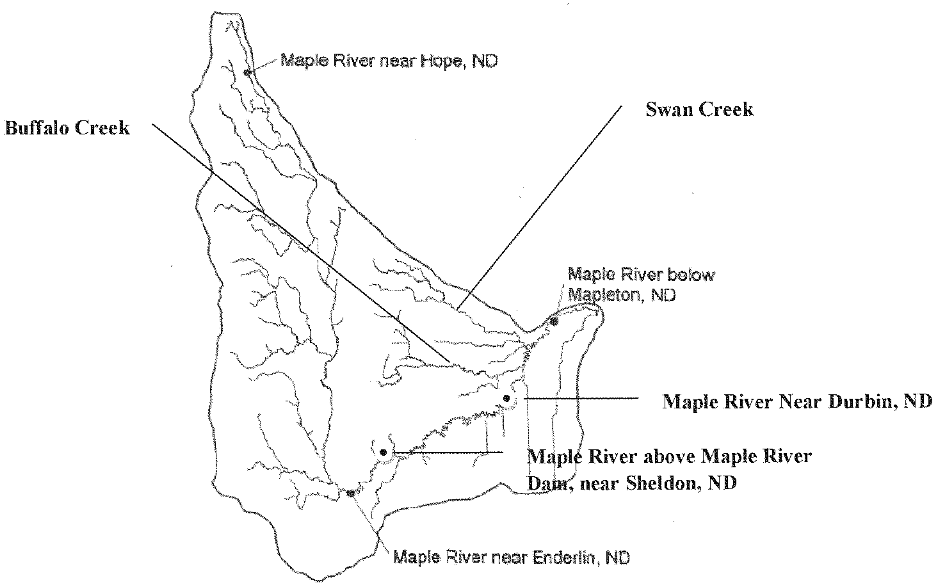


Figure 2- USGS Gage Records utilized in for Maple River Modeling

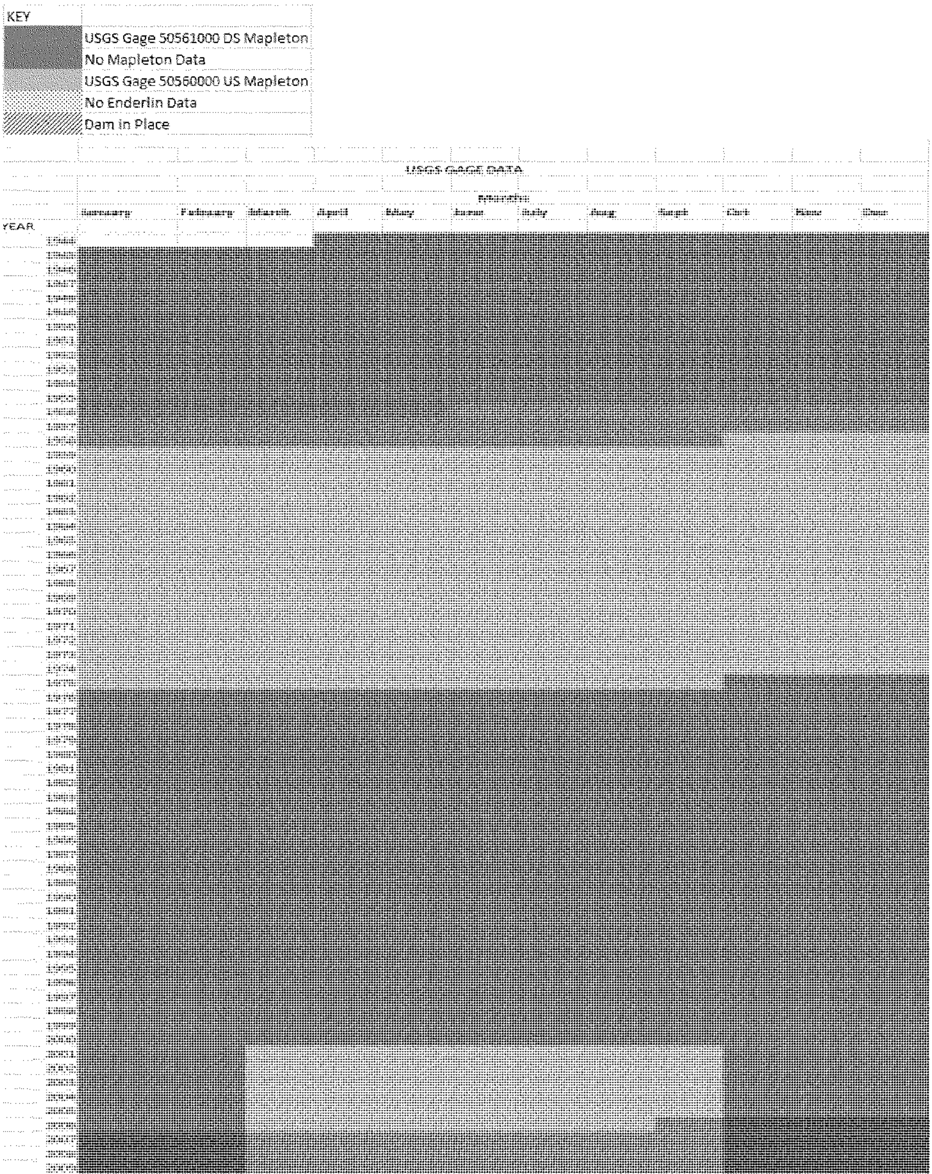


Figure 3. Justification for placing non-contributing area between the Enderlin USGS gage and the Maple River Dam

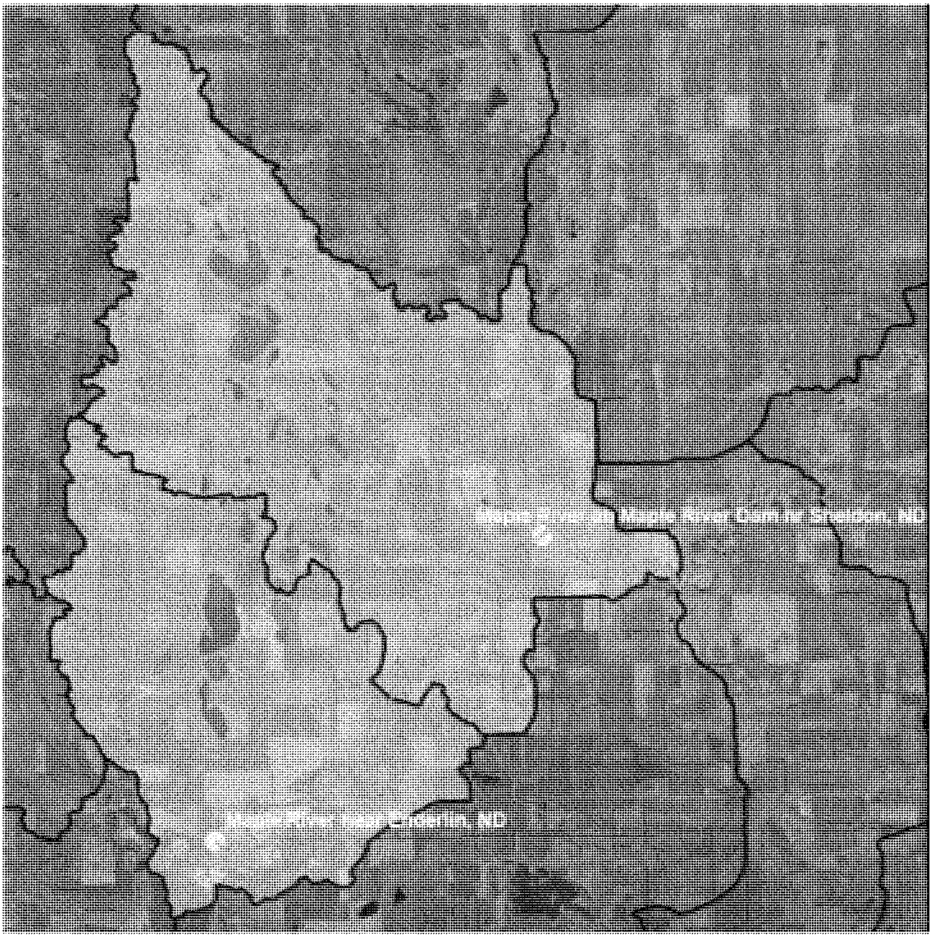


Figure 4. Channel Cross Sections

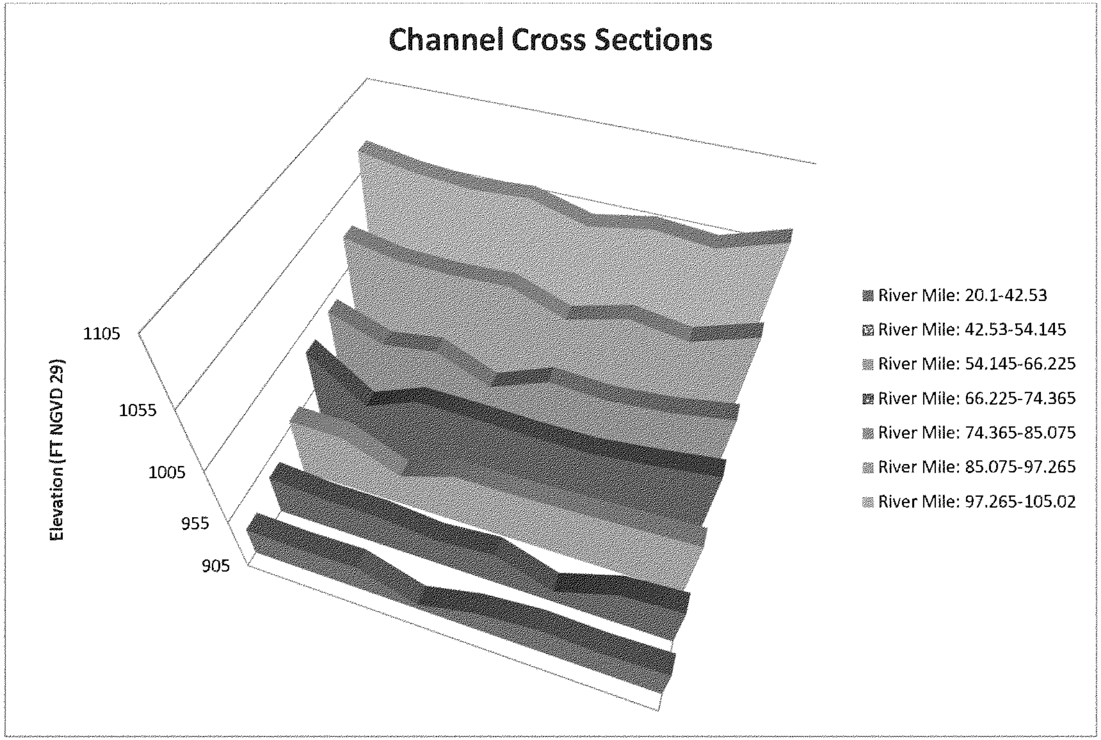


Figure 5. Aerial photograph of the Maple River near Enderlin (Source: Google Earth)

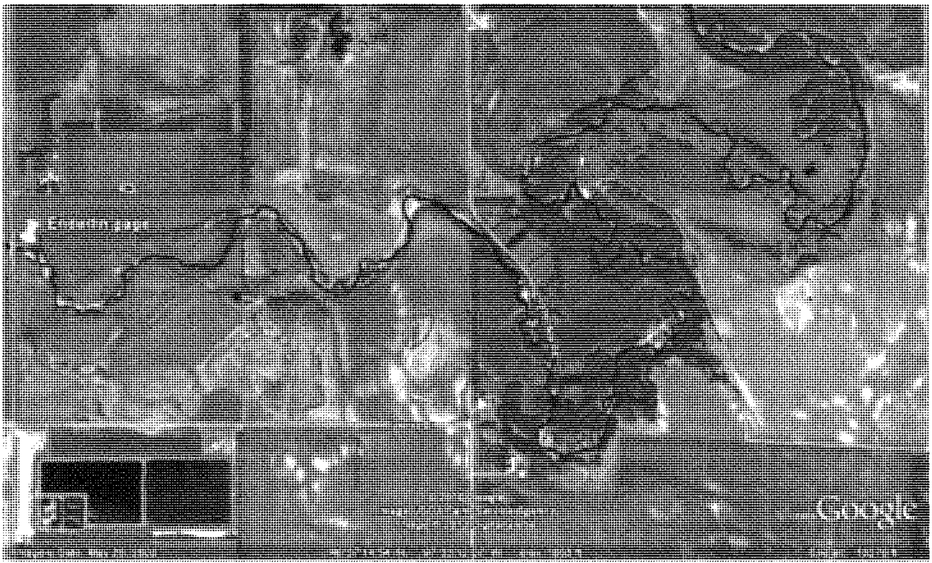


Figure 6. Aerial photograph of the Maple River near the Maple River Dam (Source: Google Earth)

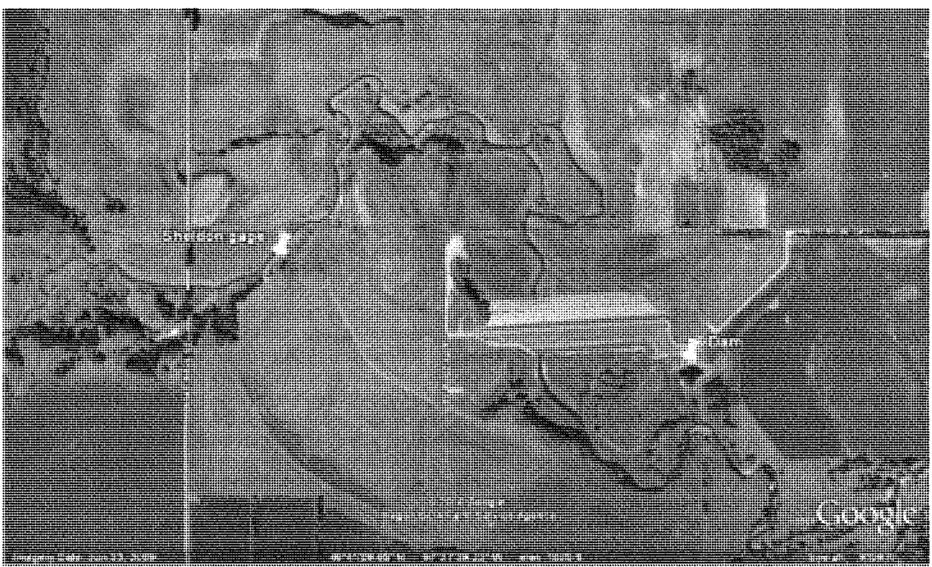


Figure 7. Aerial photograph of the Maple River near Mapleton (Source: Google Earth)

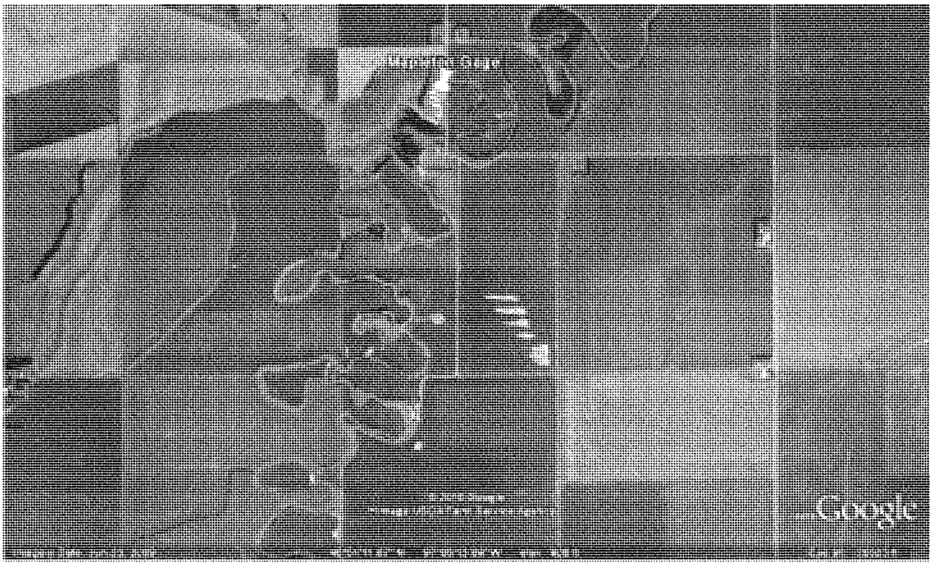


Figure 8. Maple River Dam (Source: Moore Engineering)

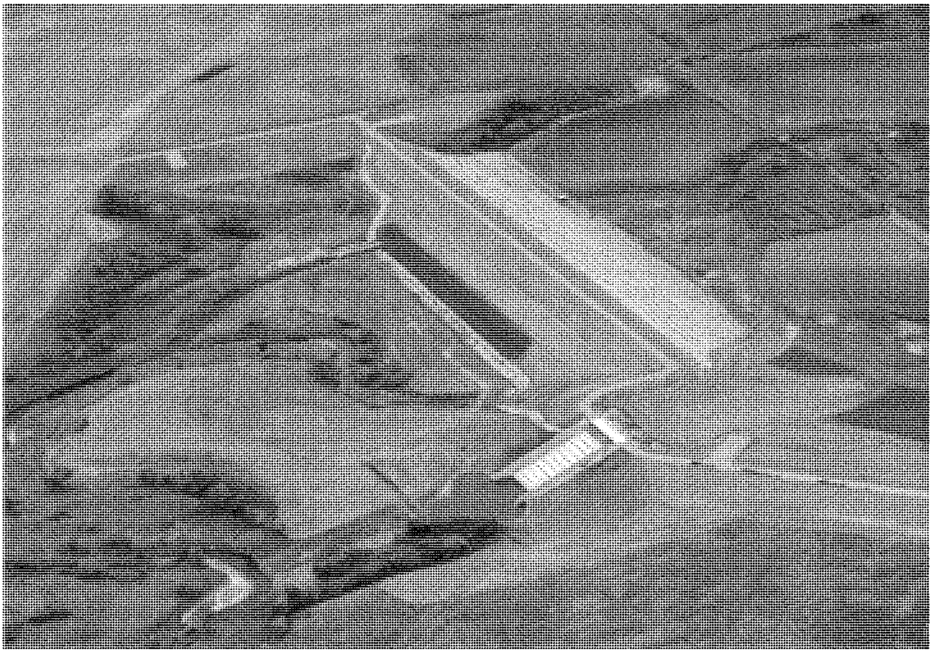


Figure 9. Maple River Dam Elevation-Storage Relationship

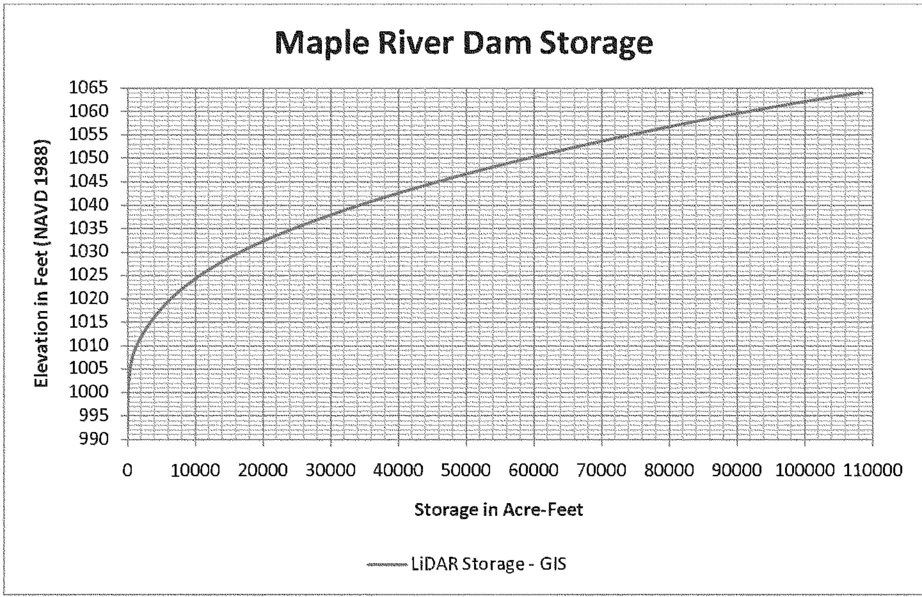


Figure 10. Maple River Dam Control Structure Rating Curve

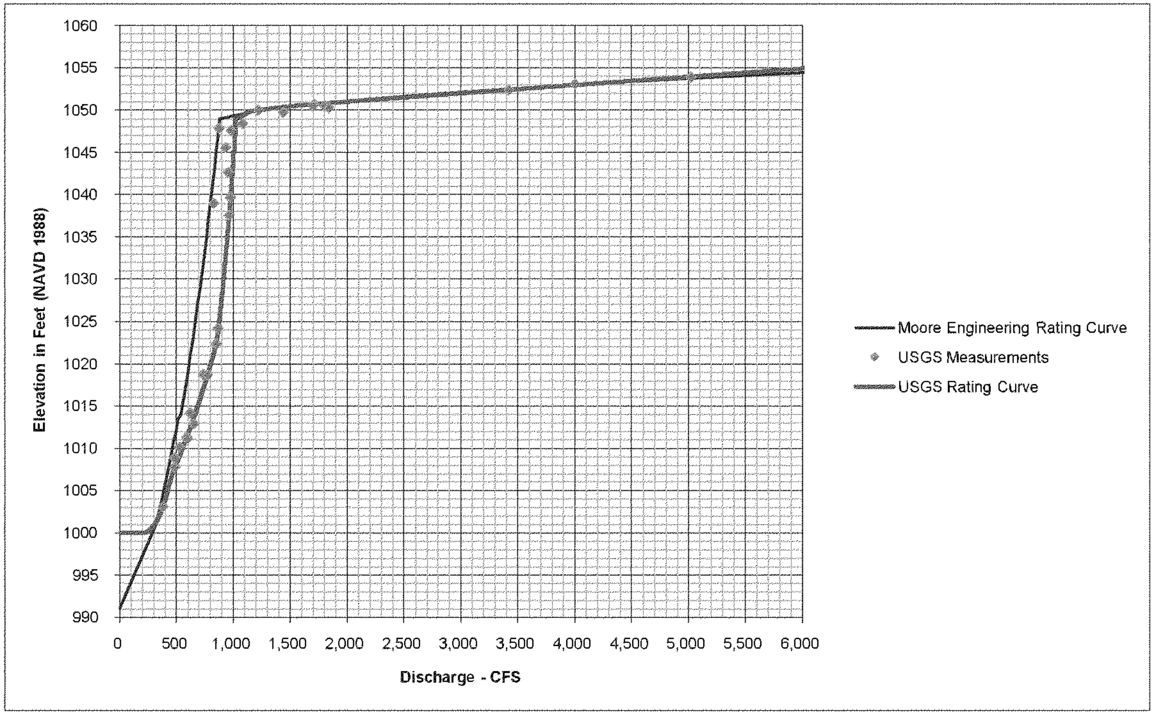


Figure 11. Breakout Flows from the Maple River to the Sheyenne River

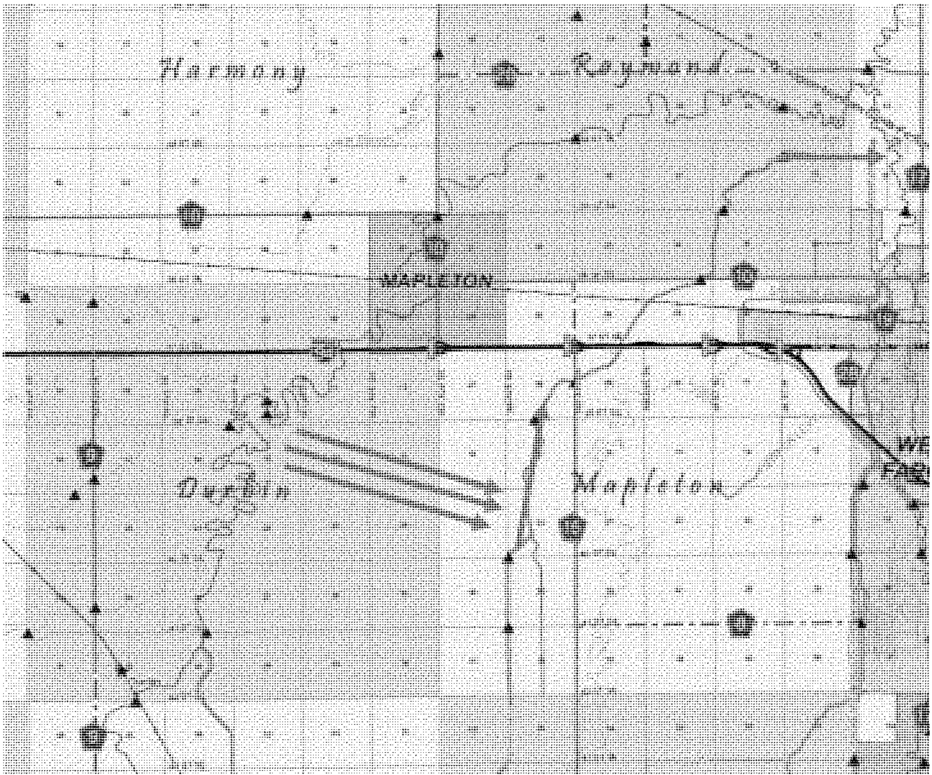


Figure 12. HMS Schematic

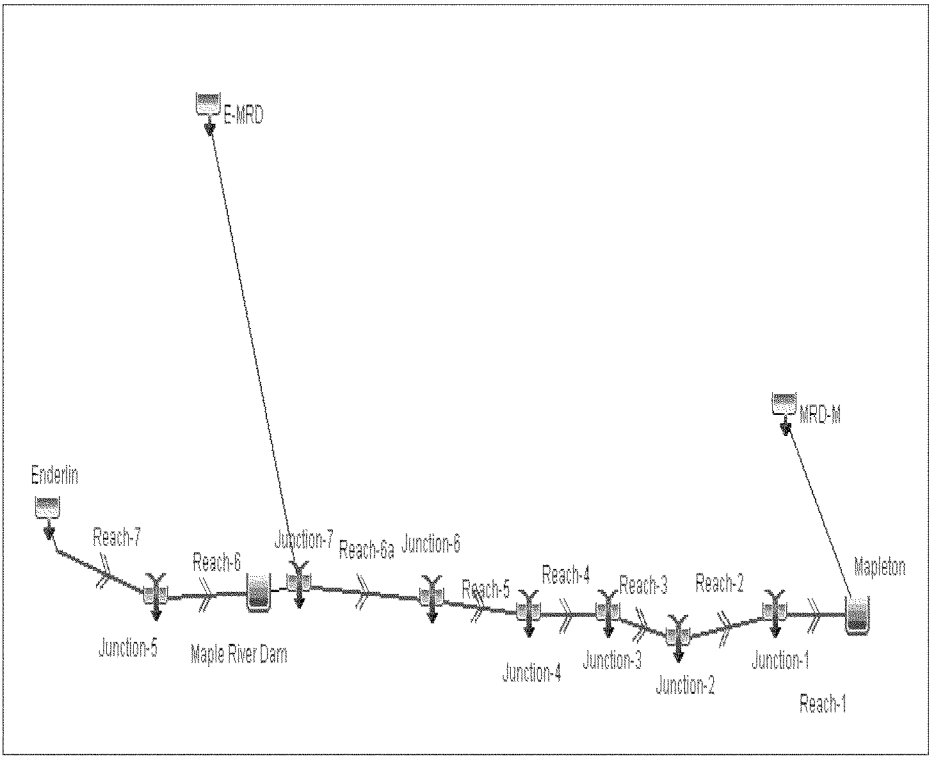


Figure 13. Dam Outflow- 2007, 2008 & 2009

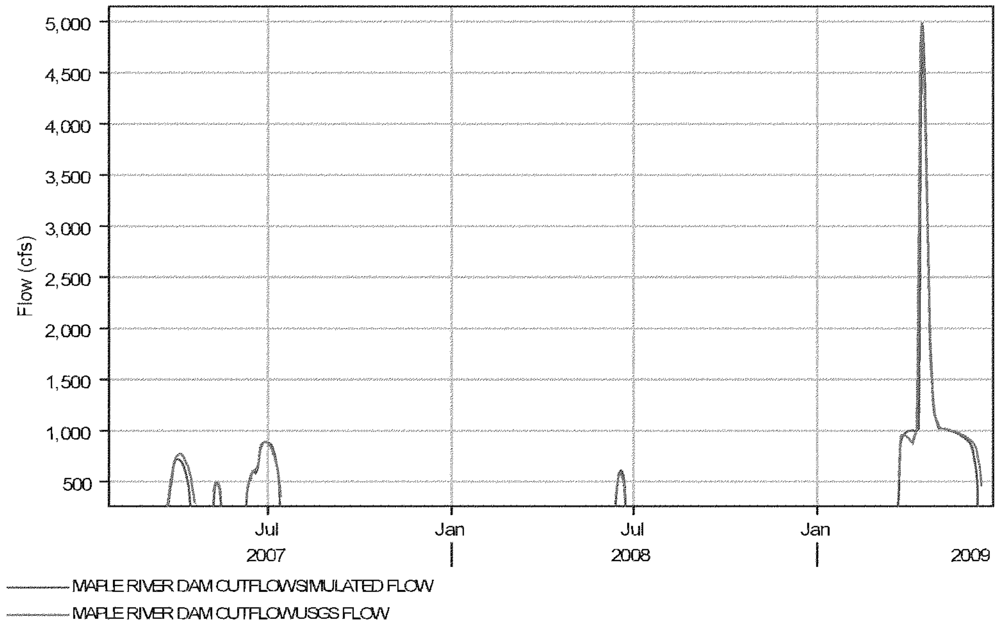


Figure 14. Elevation in Storage Pool- 2007, 2008, & 2009

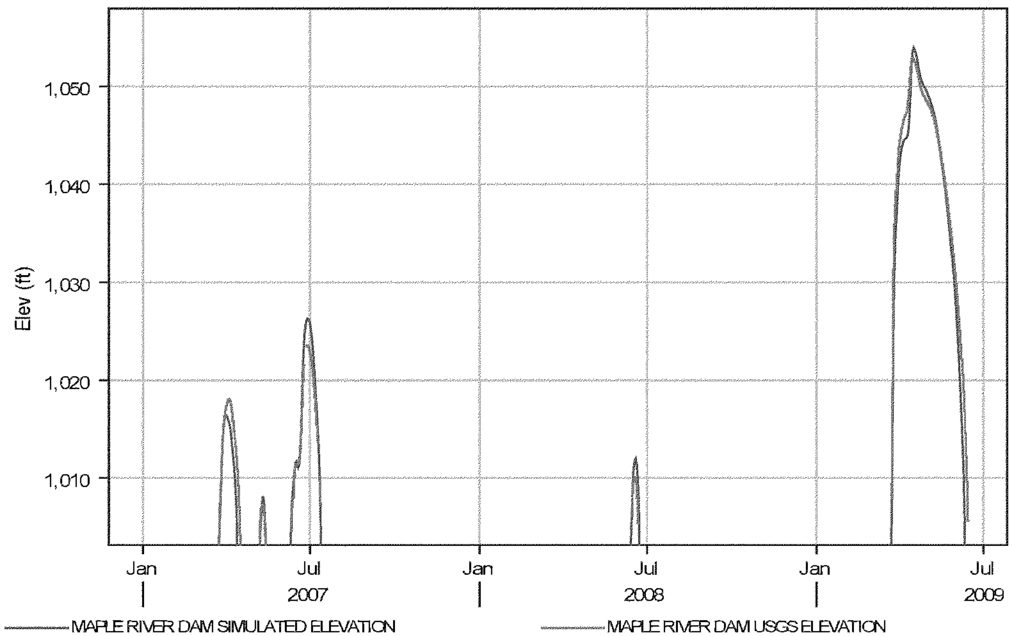
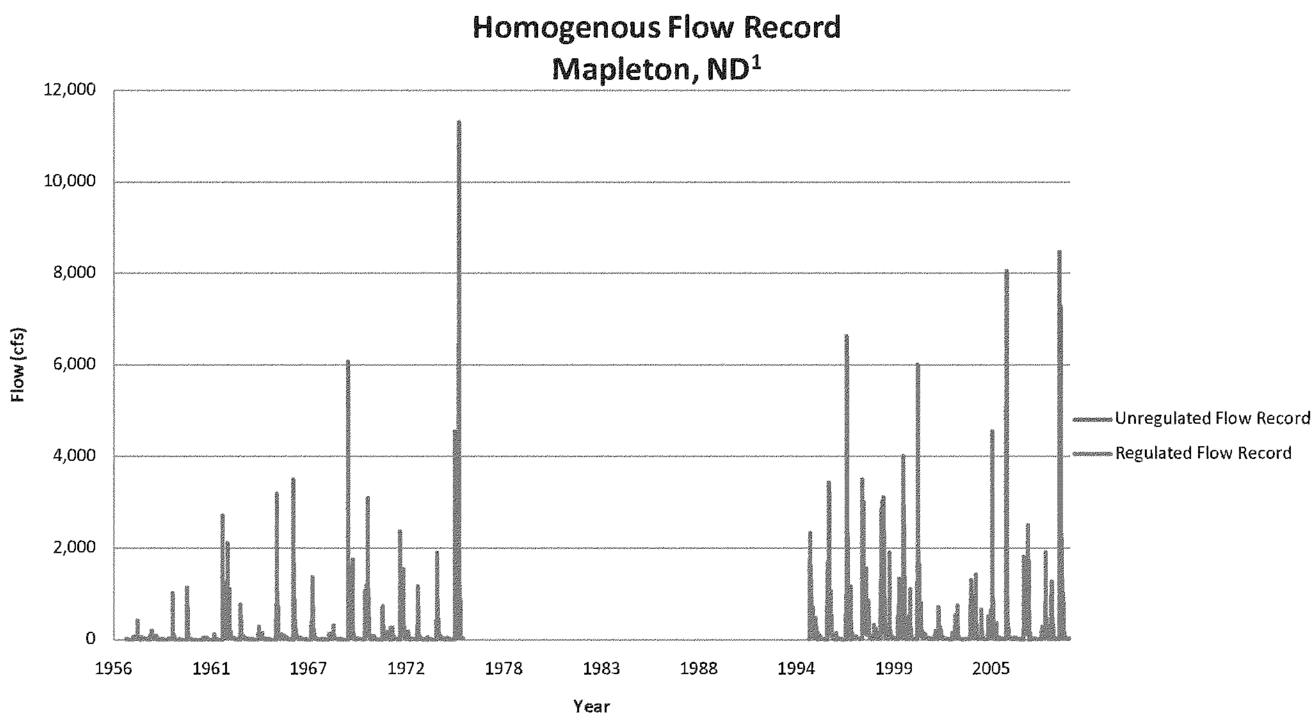


Figure 15. Homogenous Flow record at Mapleton, ND



[1]Note: No USGS streamflow data is available at the Mapleton gage from 9/30/1975-3/1/1995

Figure 16. Flow Frequency Curve and Volume Duration Curve for Outflows from Maple River Dam (Weibull PP)

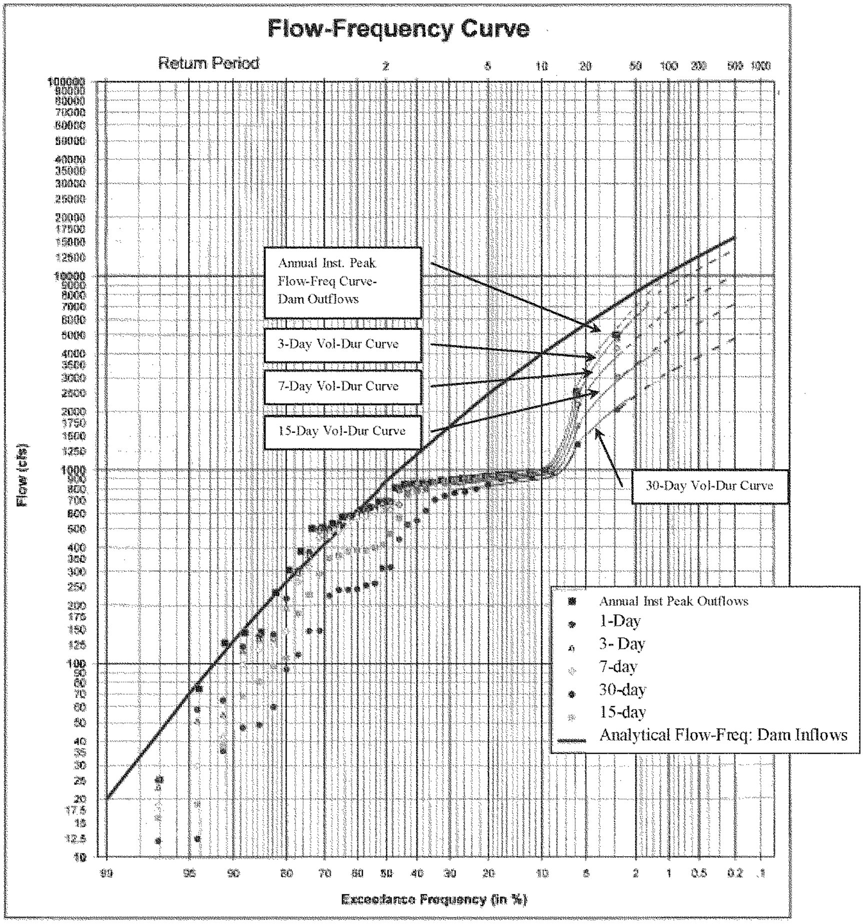


Figure 17. Relationship between Mean Daily and Annual peaks at Mapleton

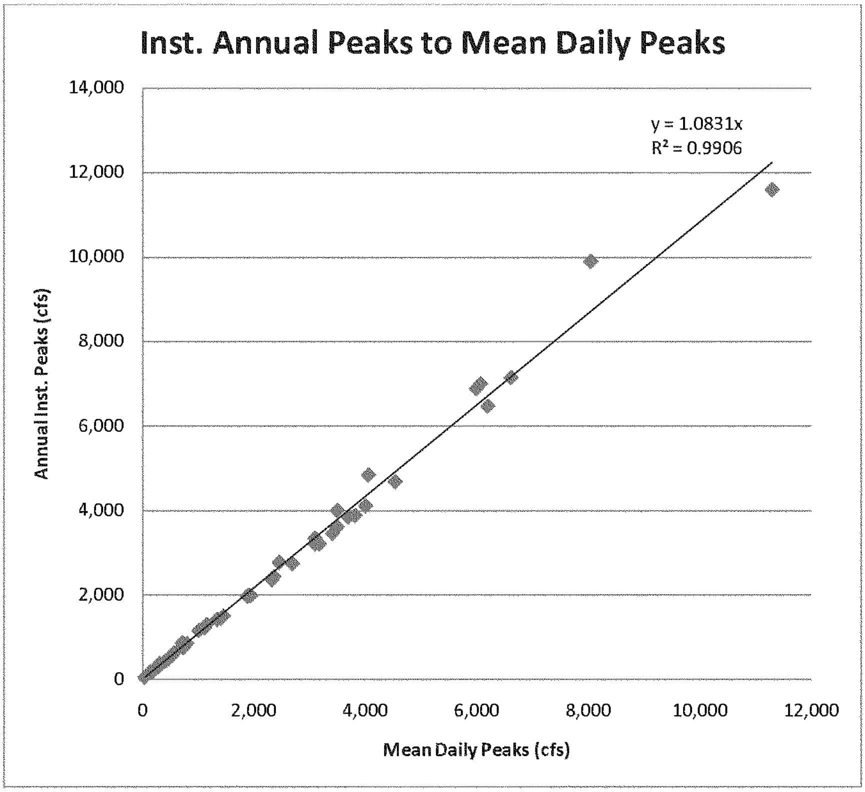


Figure 18. Instantaneous Annual Peak Flow-Frequency Curve- Mapleton (Weibull PP)

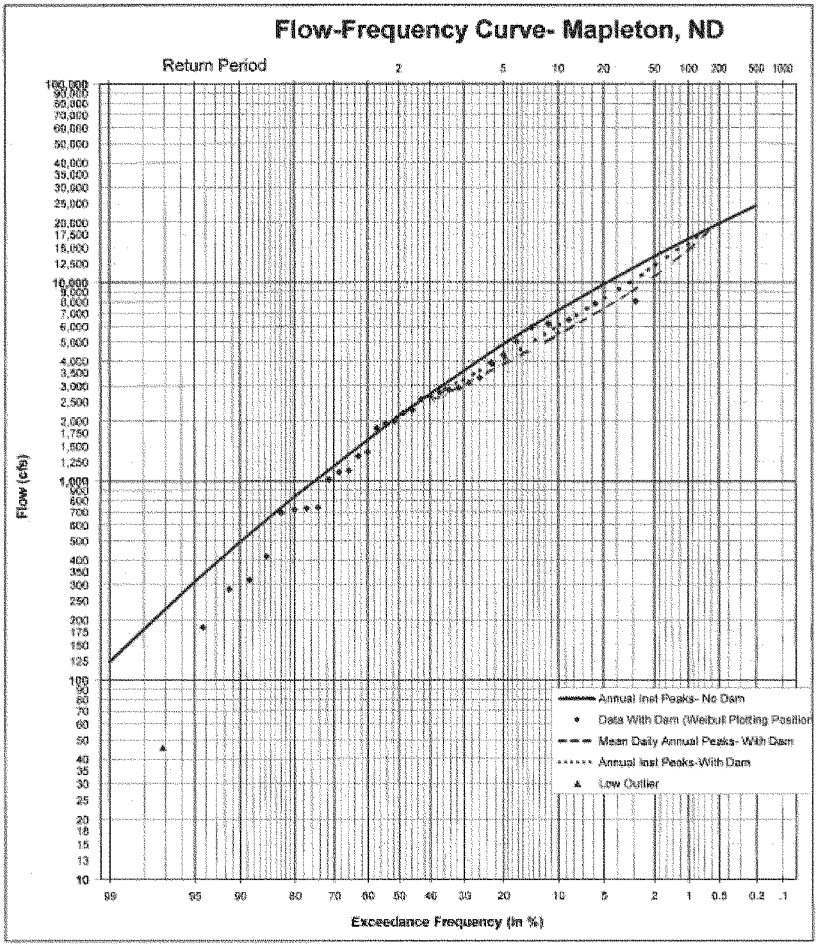


Figure 19. Volume-Duration Curves for Mapleton, ND (Dam in Place, Weibull PP)

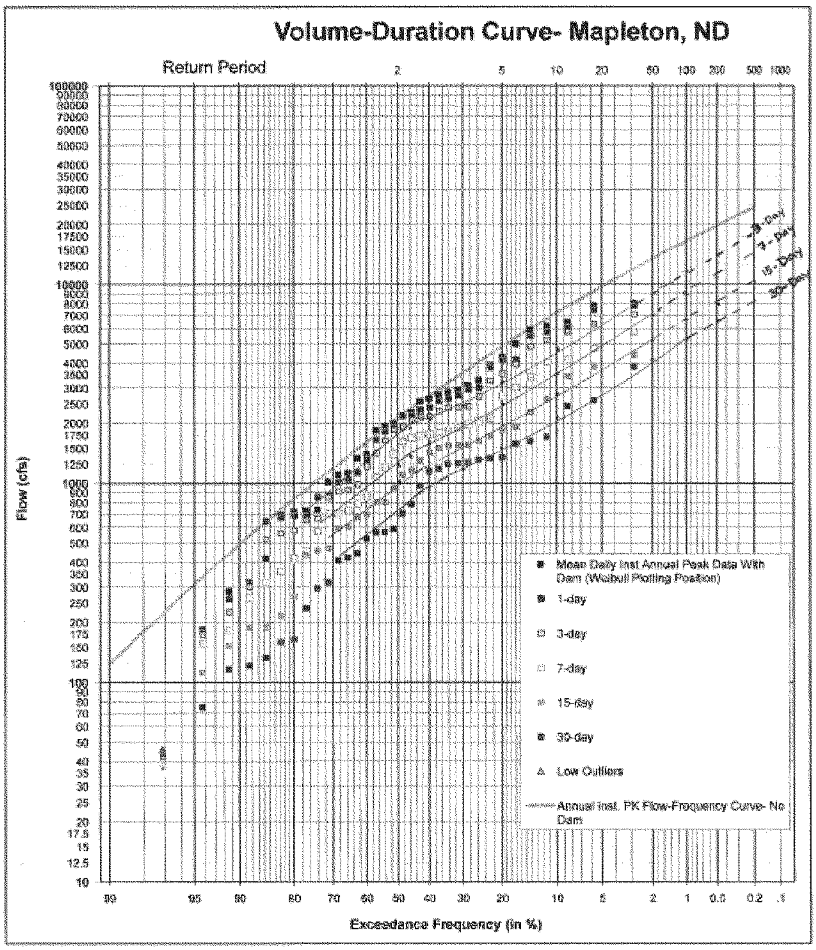


Figure 20. Rush River Watershed (*North Dakota Department of Health*)

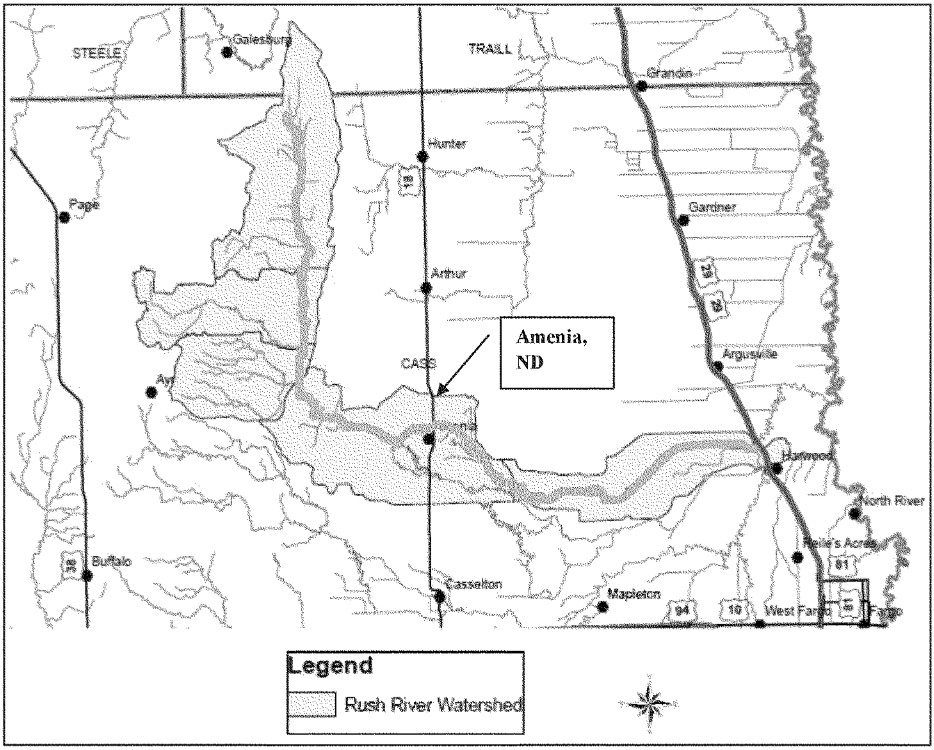


Figure 21 Annual Instantaneous Peak Discharge-Frequency; Rush River @ Amenia, ND

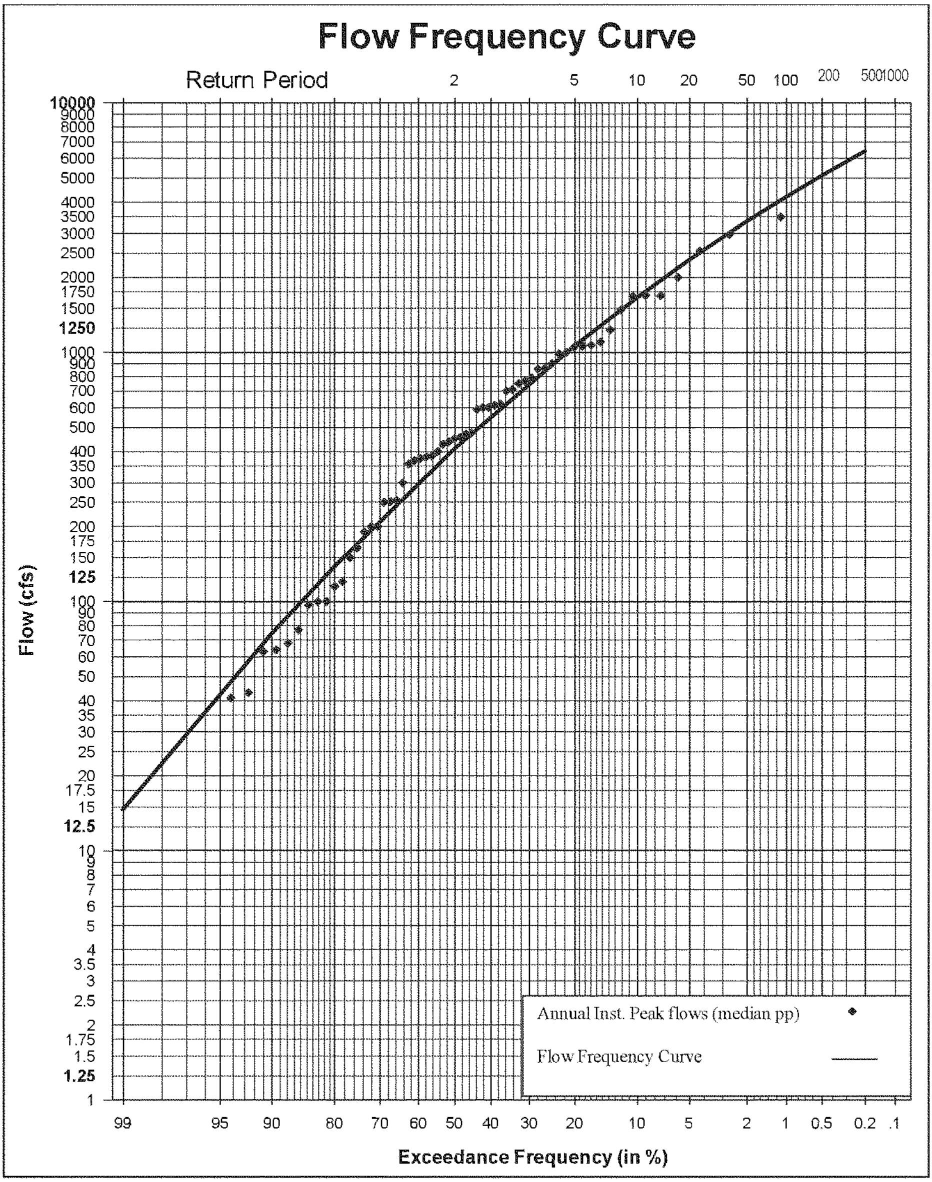


Figure 22. Gol Bridge versus Kindred Breakout Flow Relationship

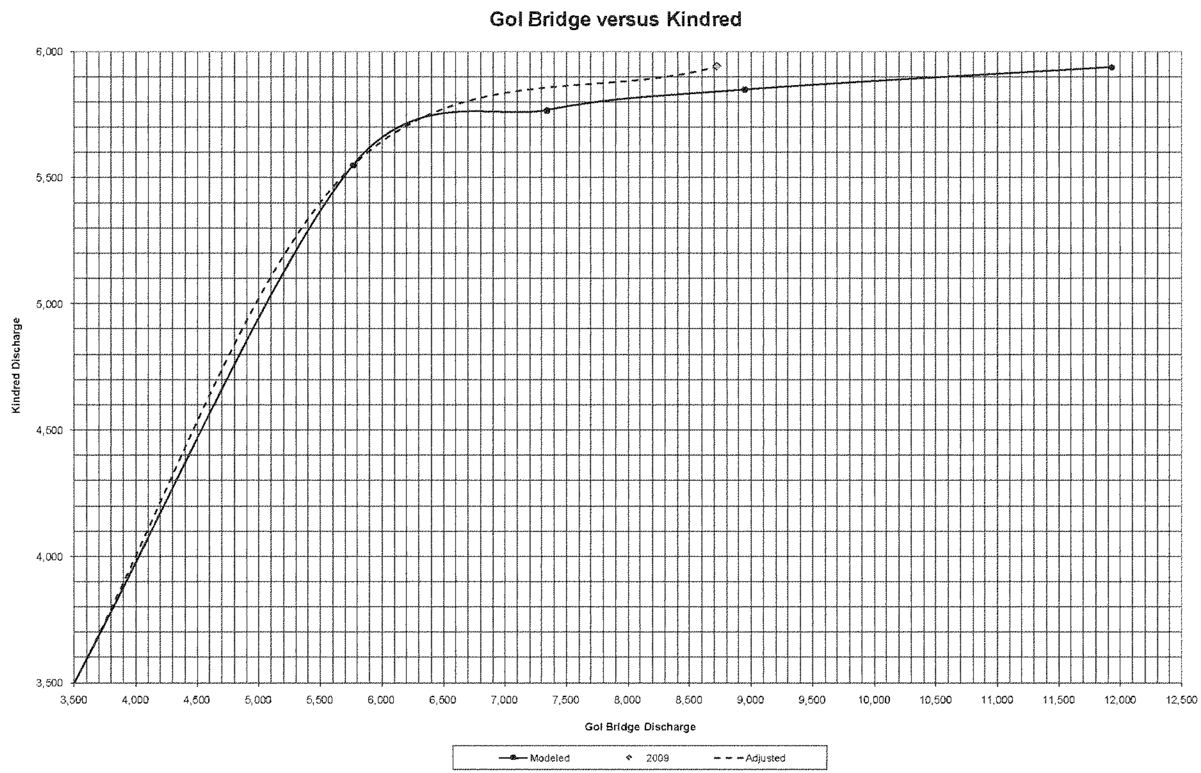


Figure 23. Flow-Frequency Curve- Gol Bridge & Kindred

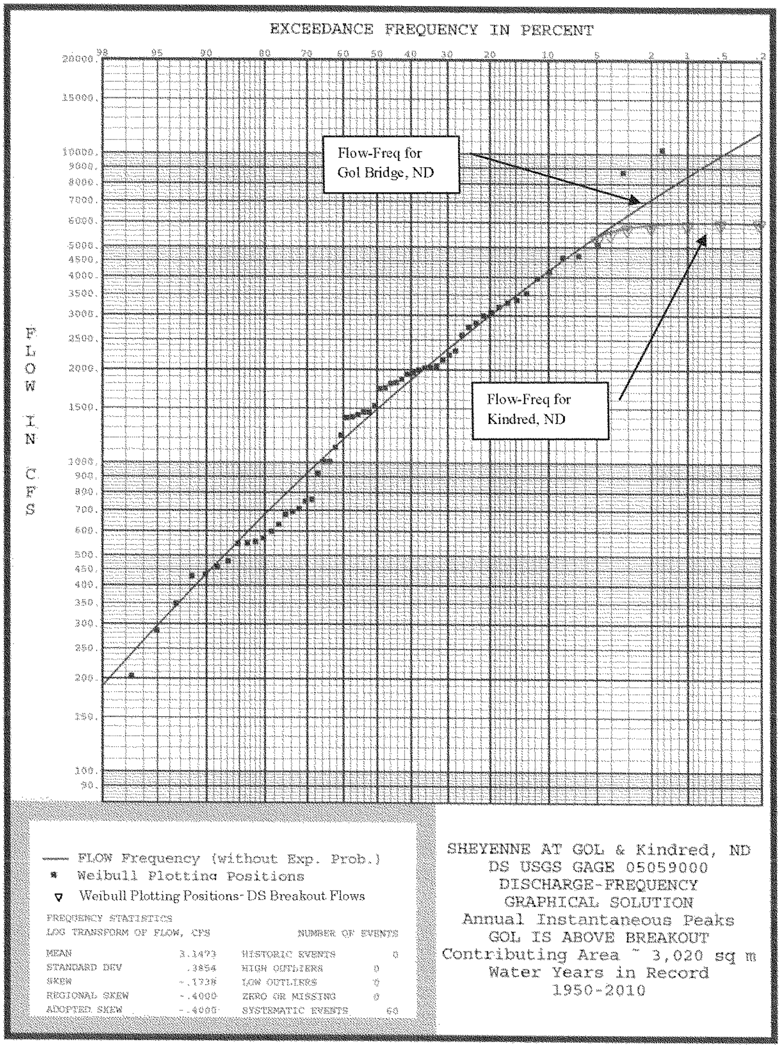


Figure 24. Annual Peak Discharge-Frequency; Sheyenne River @ West Fargo

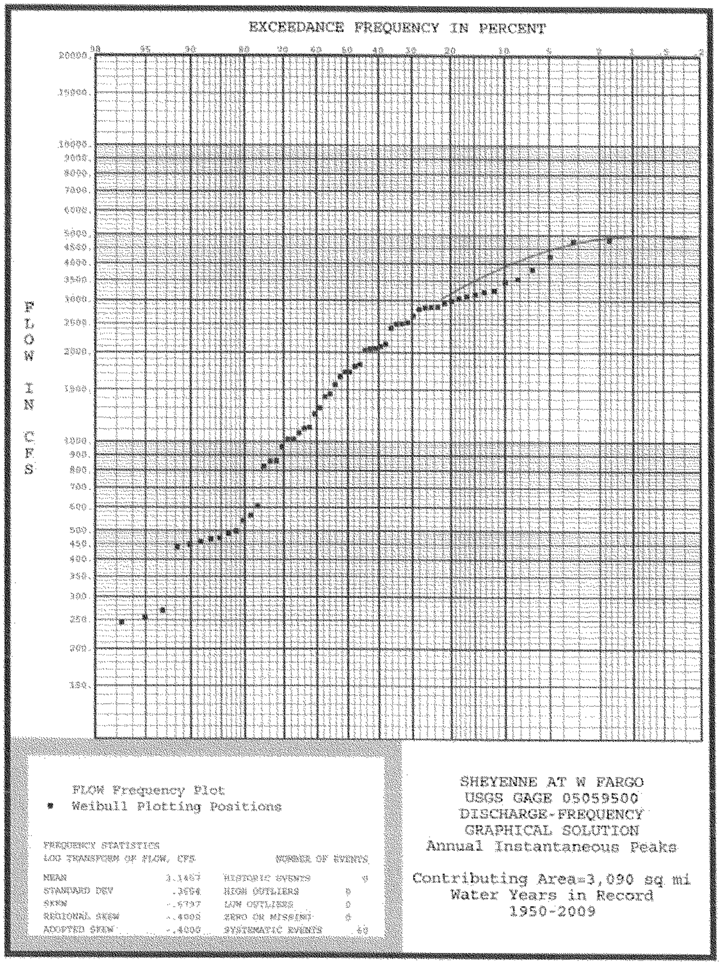


Figure 25. Estimated Discharge Volume Duration Frequencies; Sheyenne River @ West Fargo

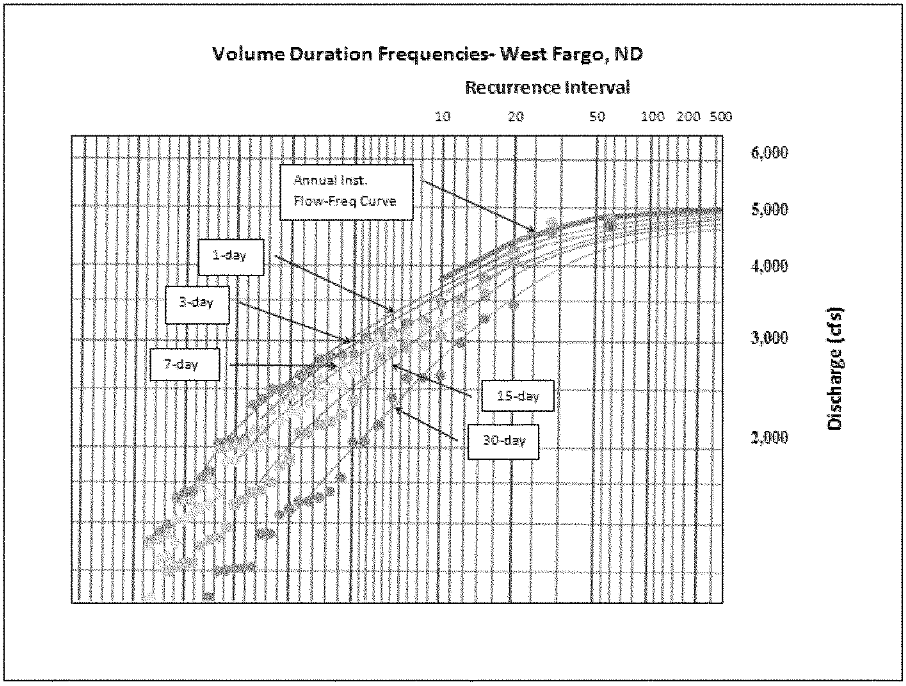


Figure 26. Coincident Discharge-Frequency; Wild Rice River @ Abercrombie when Sheyenne Peaks at Gol Bridge

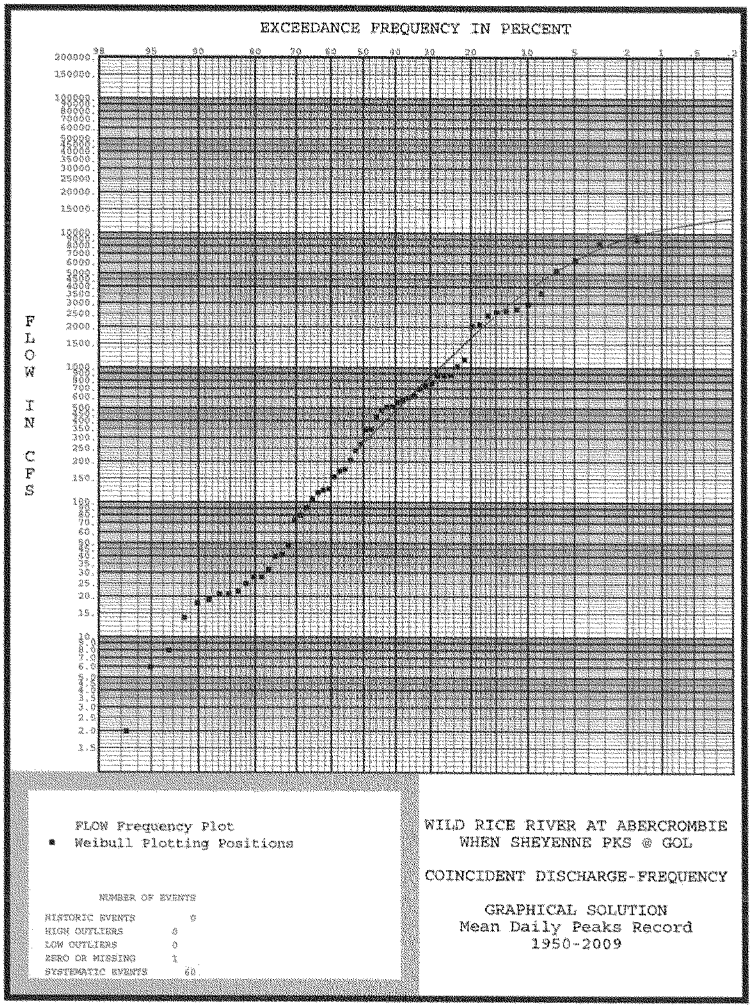


Figure 27. Coincident Discharge-Frequency; Wild Rice River @ Abercrombie when Mapleton Peaks

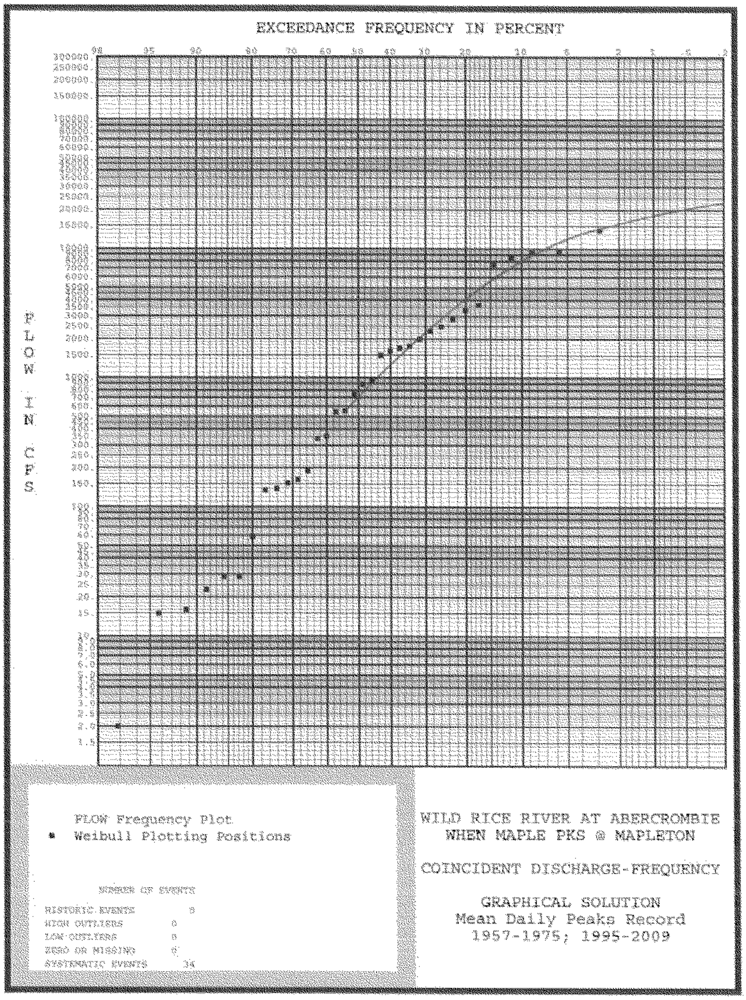


Figure 28. Coincident Discharge-Frequency; Wild Rice River @ Abercrombie when Amenia Peaks

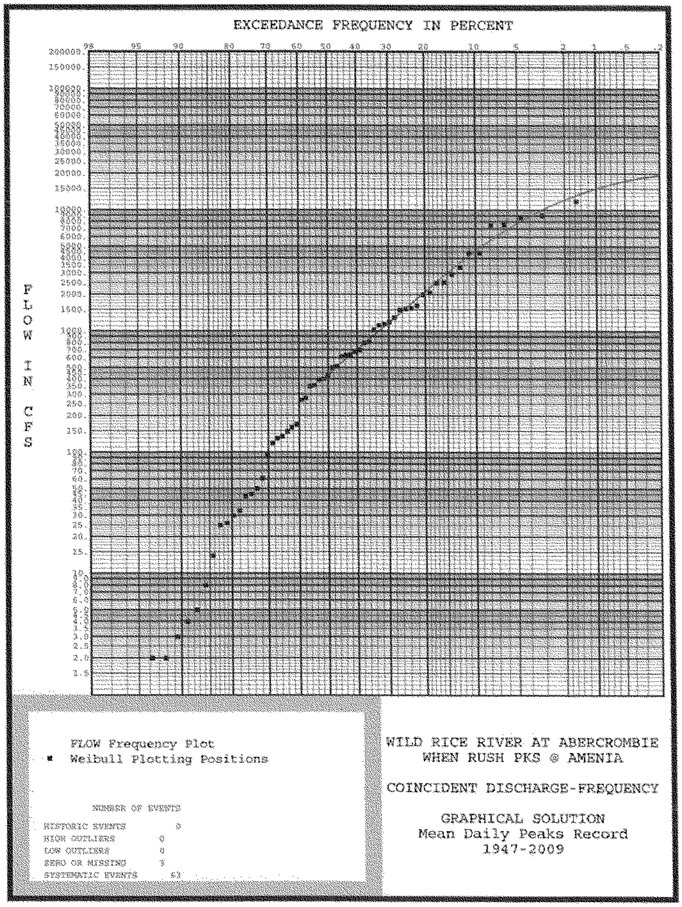


Figure 29. Coincident Discharge-Frequency; Wild Rice River @ Abercrombie when Red Peaks

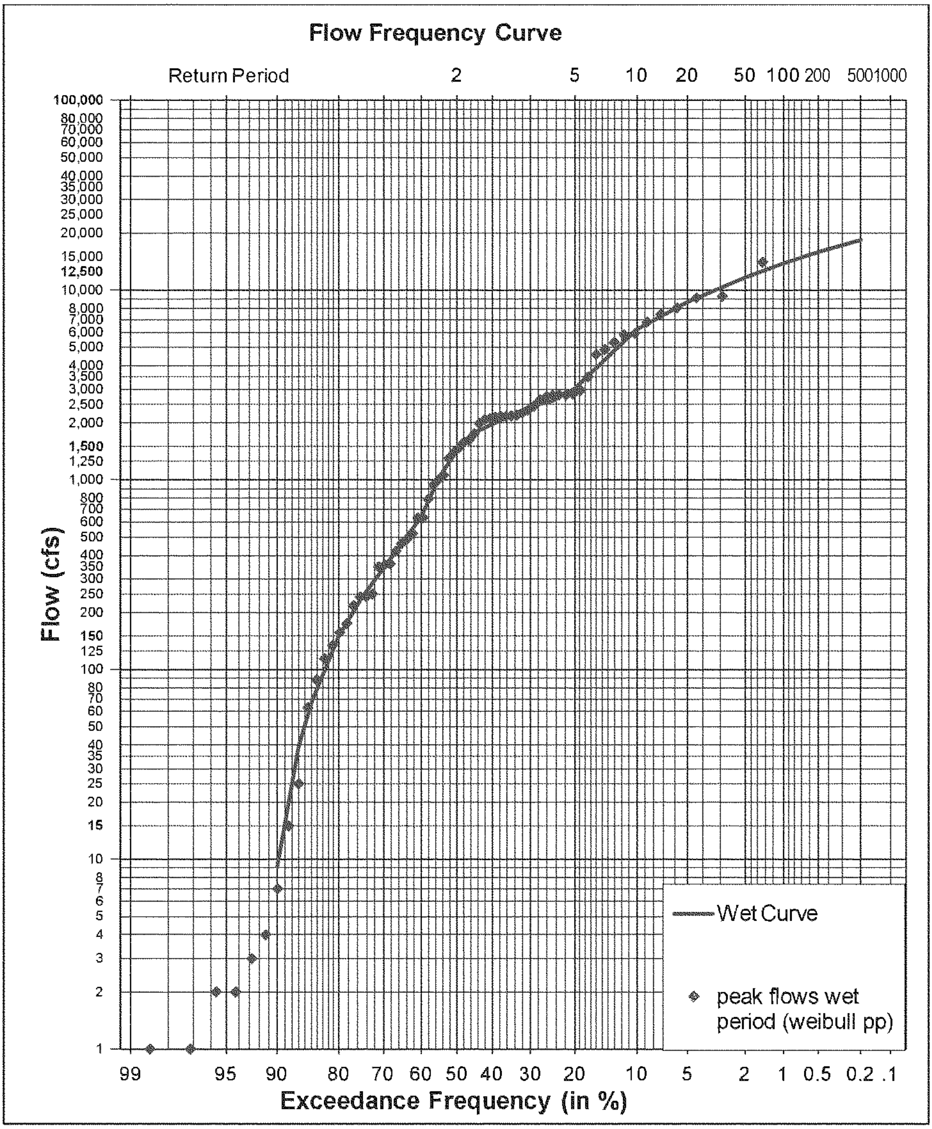


Figure 30. Coincident Discharge-Frequency; Red River @ Hickson when GOL Peaks

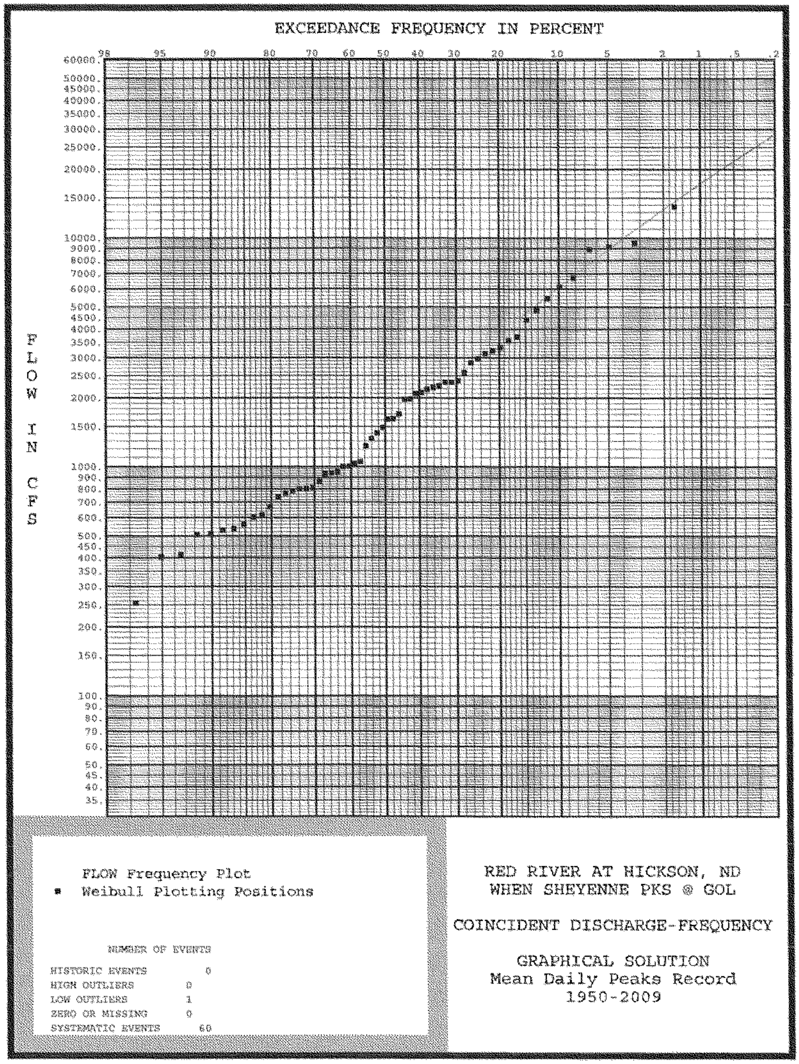


Figure 31. Coincident Discharge-Frequency; Red River @ Hickson when Mapleton Peaks

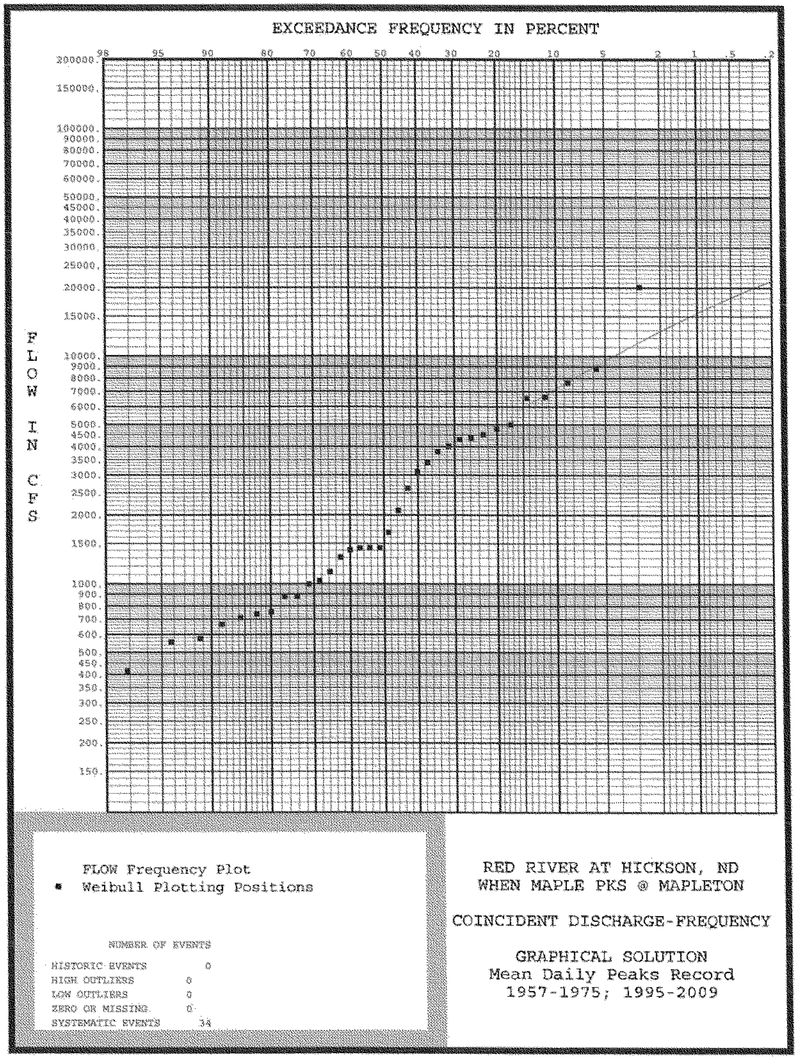


Figure 32. Coincident Discharge-Frequency; Red River @ Hickson when Amenia Peaks

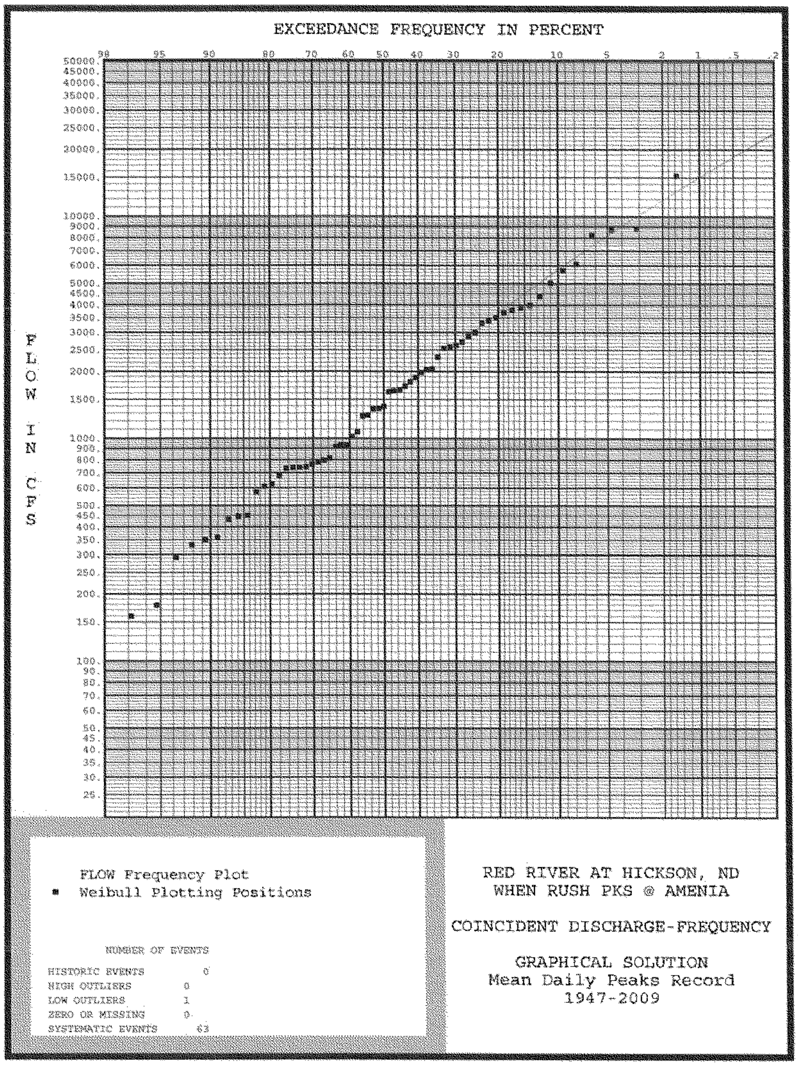


Figure 33 Coincident Discharge-Frequency; Red River @ Hickson when Abercrombie Peaks

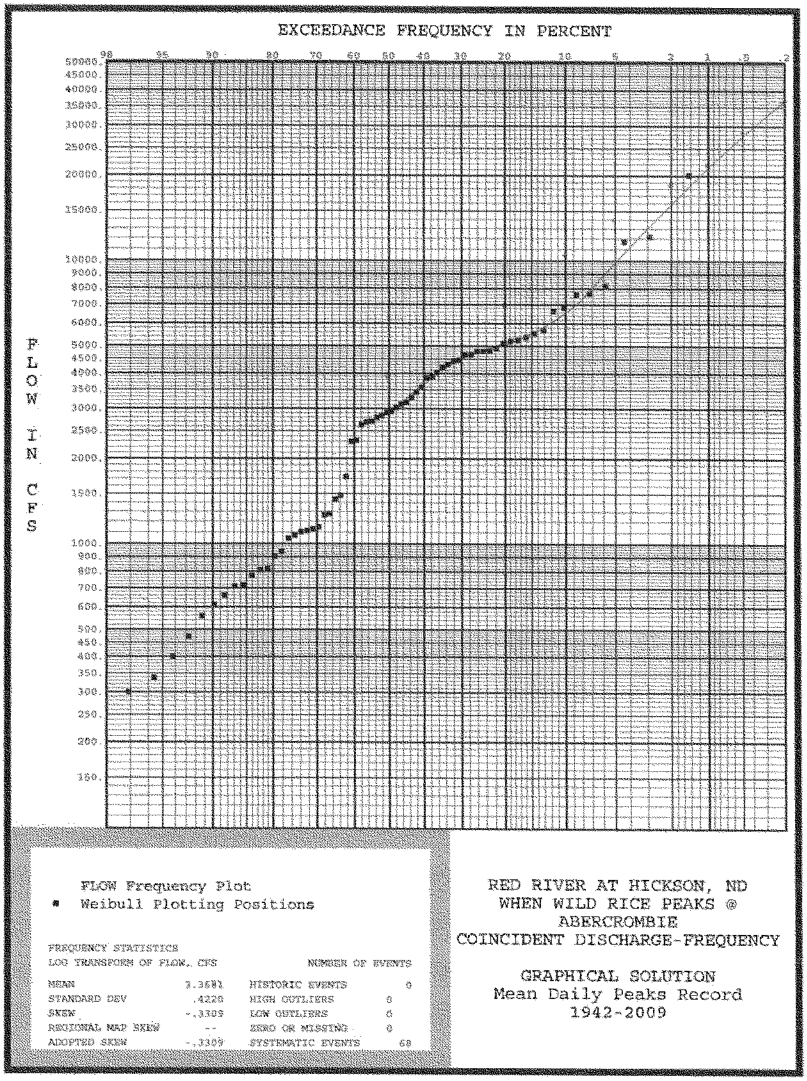


Figure 34 Coincident Discharge-Frequency; Red River @ Confluence when Wild Rice, ND Peaks

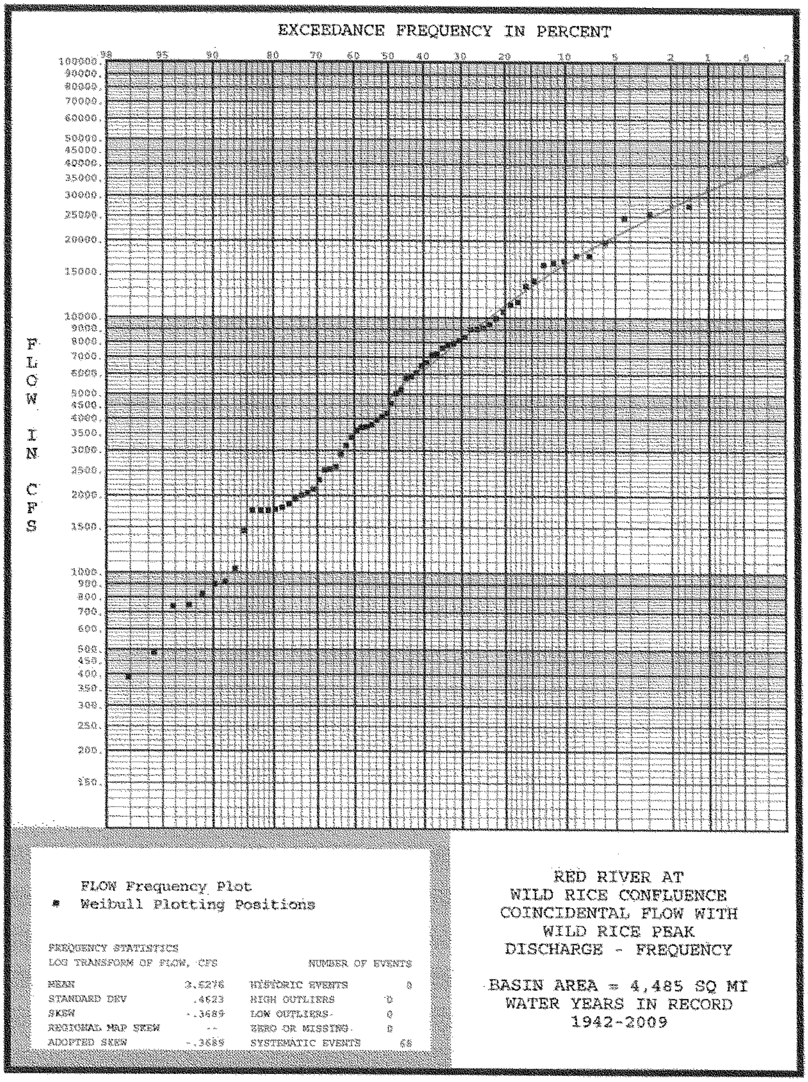
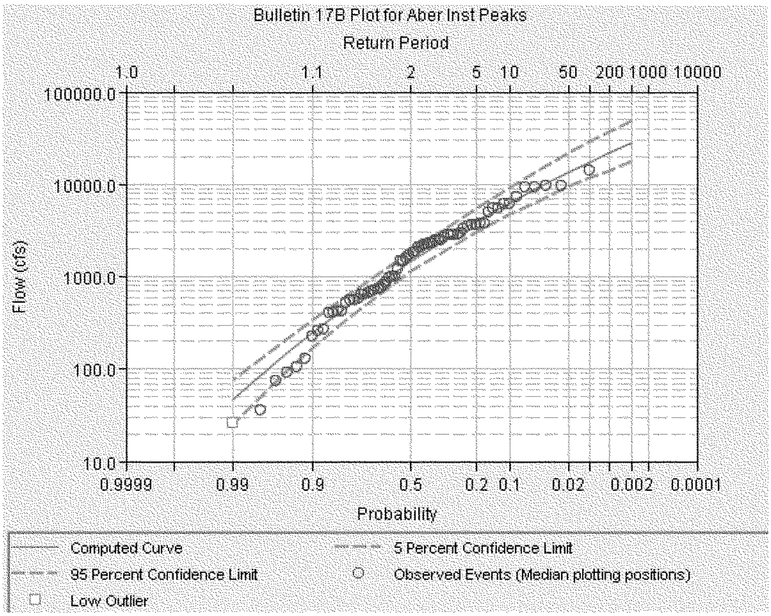


Figure 35. Annual Peak Discharge-Frequency Wild Rice River, ND @ Abercrombie



Results for Aber Inst Peaks

Frequency Curve for: Inst Pks

Percent Chance Exceedance	Computed Curve Flow in cfs	Confidence Limits Flow in cfs	
		0.05	0.95
0.2	27863.0	49414.9	17806.6
0.5	21743.1	37204.5	14255.8
1.0	17537.7	29109.4	11749.1
2.0	13716.4	22007.5	9410.4
5.0	9282.5	14145.3	6598.2
10.0	6415.1	9343.6	4698.8
20.0	3983.0	5512.0	3010.7
50.0	1459.3	1892.0	1129.7
80.0	471.3	621.8	342.2
90.0	247.8	341.3	167.9
95.0	141.8	205.0	89.4
99.0	46.4	75.2	25.0

System Statistics

Log Transform: Flow

Statistic	Value
Mean	3.126
Standard Dev	0.555
Station Skew	-0.593
Regional Skew	-0.230
Weighted Skew	-0.419
Adopted Skew	-0.419

Number of Events

Event	Number
Historic Events	0
High Outliers	0
Low Outliers	1
Zero Or Missing	0
Systematic Events	68
Historic Period	

Figure 36. Coincident Discharge-Frequency; Red River @ Sheyenne Confluence when GOL Peaks

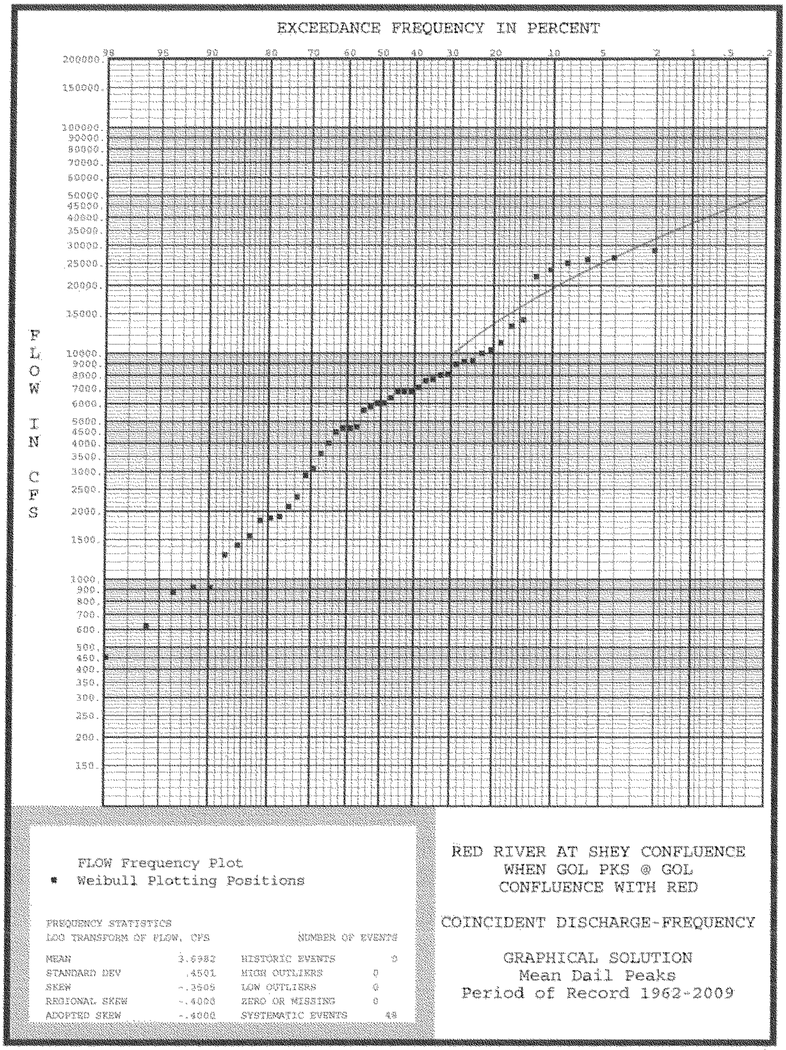


Figure 37. Coincident Discharge-Frequency; Red River @ Sheyenne Confluence when Mapleton Peaks

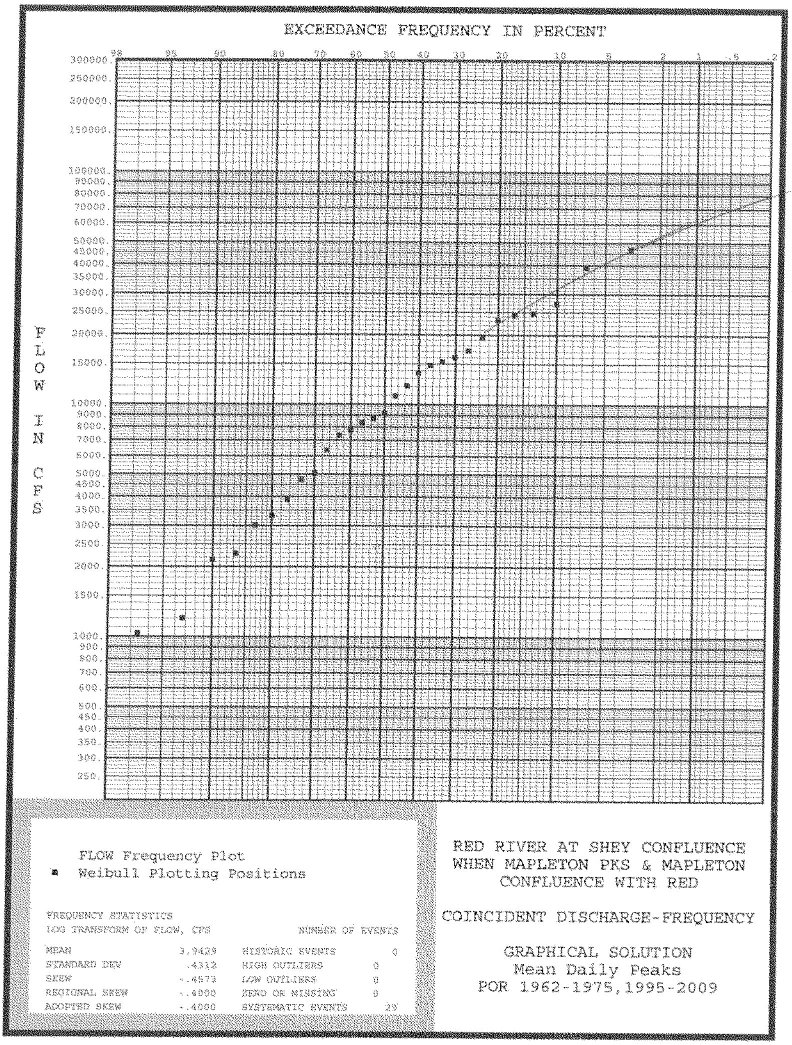


Figure 38. Coincident Discharge-Frequency; Red River @ Sheyenne Confluence when Amenia Peaks

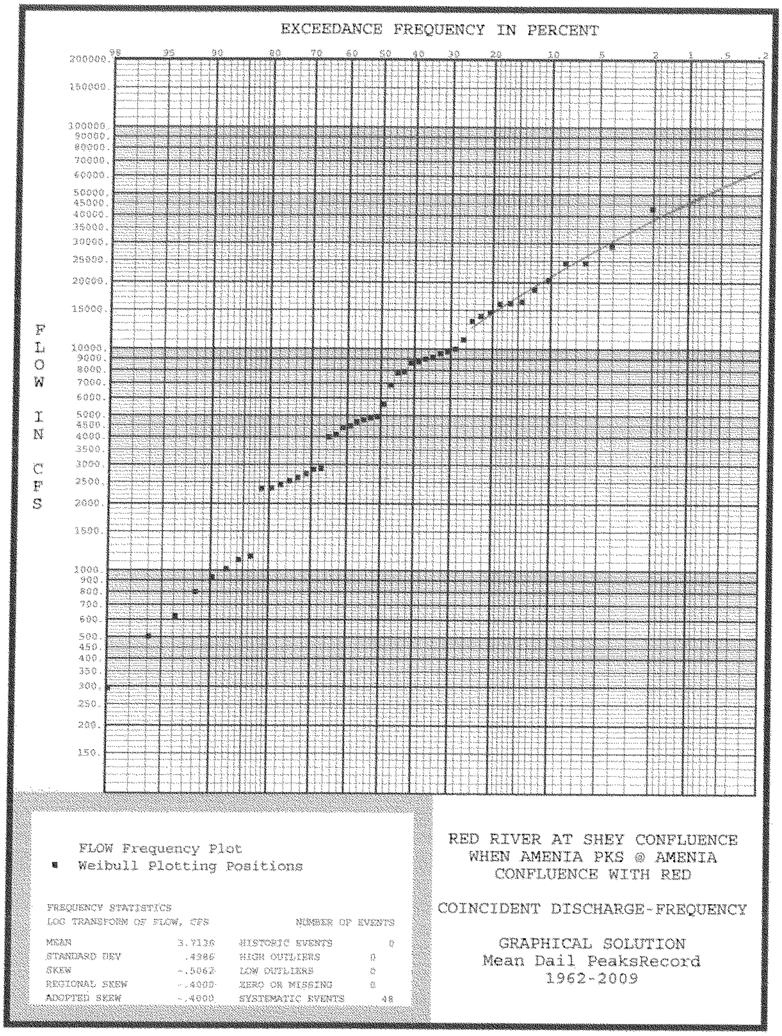
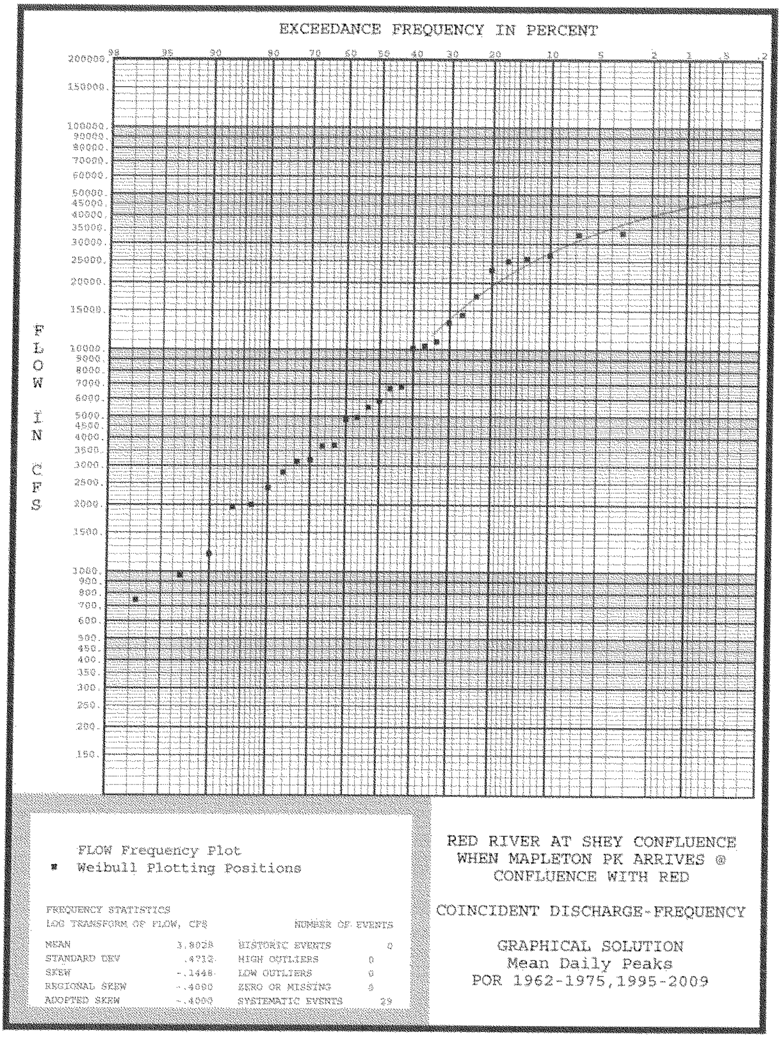


Figure 39. Coincident Discharge-Frequency; Red River @ Sheyenne Confluence when Mapleton Peaks Arrive at Sheyenne Confluence



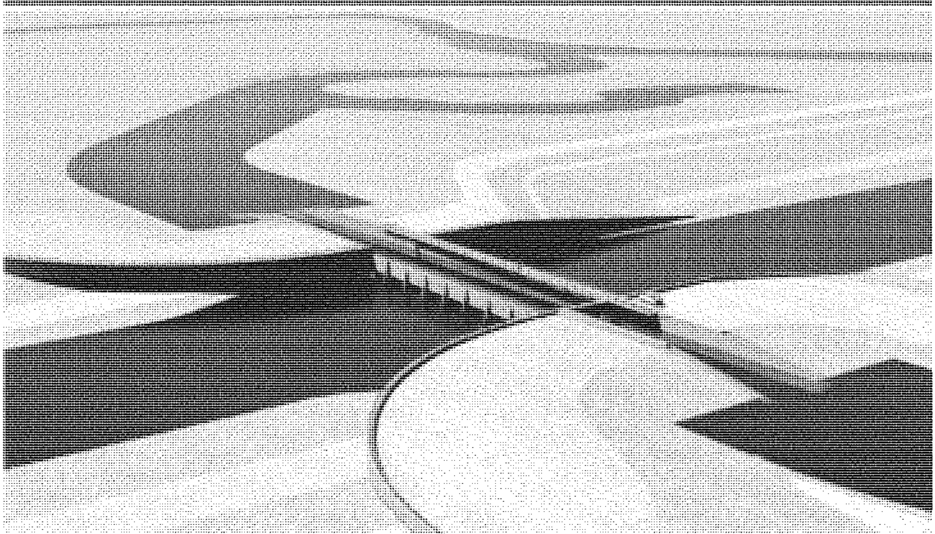
RED RIVER DIVERSION

FARGO-MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT

FEASIBILITY STUDY - PHASE 4

Volume 1

General Report



Report for the US Army Corps of Engineers
and the cities of Fargo, ND and Moorhead, MN

Prepared by:
Moore Engineering, Inc.; Houston Engineering, Inc.;
Barr Engineering Company; and HDR Engineering, Inc.

April 2011

RED RIVER DIVERSION

FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4

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VOLUME 1

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FINAL – Version April 19, 2011

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1.0 Background

The Red River of the North and its tributaries have posed a repeated flood threat to the Cities of Fargo, North Dakota and Moorhead, Minnesota as well as to the surrounding communities. Although people and organizations (including support from the U.S. Army Corps of Engineers (USACE)) have demonstrated significant skill in defending themselves against floods, the efforts can be massive and highly disruptive to the cities and the surrounding communities. In addition, there is considerable concern over the prospect of larger floods than those that have recently occurred and that could be defended against. As a reference, the flood of record occurred during the spring of 2009, and 11 out of the 20 largest flood events in the 108 years of record happened in the past 18 years. Various plans have been formulated to varying degrees that address portions of the flood risk. However, no previous plan has offered an integrated and more permanent solution to deal with such flood risk.

This study, following several previous levels of feasibility completed over the past two years, looks at the Locally Preferred Plan (LPP) diversion alternative with upstream staging to provide flood damage reduction up to the 0.2-percent chance flood event in the Red River of the North (i.e., the 500-yr event in the Red River of the North is the design flood) for nearly 200,000 people and 80 square miles of infrastructure. For this report the LPP diversion alternative is designated as the plan comparable to the North Dakota East alignment with a maximum diversion discharge of 35,000 cfs and no upstream staging. The Federally Comparable Plan (FCP) is the Minnesota Short Diversion alignment with a maximum diversion discharge of 35,000 cfs and no upstream staging.

The primary reason for the switch in the project design concept of the LPP from the previous Phase 3 (diversion only) to the current Phase 4 (diversion and storage) of the feasibility study is as follows. To provide flood damage reduction, any proposed action not only has to deal with the peak flow of the design flood hydrograph, but also with the associated flood hydrograph volume. Without some staging or off-channel engineered storage immediately upstream of the diversion works, the proposed diversion would result in increased flood levels that could extend to the Canadian border and beyond, with approximately 4,500 structures impacted. Staging and storing water immediately upstream of the diversion works would be limited to a well defined area, as required by the National Environmental Policy Act (NEPA), with approximately 800 structures impacted.

2.0 Study Approach and Report Organization

The work carried out by the Consultant from Phase 1 through Phase 3 of this study was based on a project design concept that relied on diversion only, and it included the feasibility evaluation of four diversion alignments and eight values for the maximum diversion discharge. This feasibility analysis together with that performed by the USACE (which looked at other options) led to the determination of the National Economic Development (NED) plan and to the selection of the LPP and FCP (see Figure 1). The previous Phase 3 of this study developed the feasibility design and cost estimates for two alternative alignments of the proposed diversion, one through Minnesota (the FCP) and one through North Dakota (the LPP), in both cases considering diversion works capable of diverting 35,000 cfs from the Red River of the North and Wild Rice River (ND) during a 0.2-percent chance flood event in the Red River of the North. The feasibility analysis in Phase 3 of this study was based on the Phase 3.1 hydrology produced by the USACE (see Appendix A), which was completed using up to date data and considerations for a wet/dry cycle in the basin. Because the project design concept relied on a diversion only, the work conducted in Phase 3 was done using a one-dimensional (1D) HEC-RAS steady flow model for project feasibility design. However, a 1D HEC-RAS unsteady flow model had to be used for evaluation of impacts on flood levels downstream of the diversion outlet, as such impacts could depend on the timing of the flows and volumes of water being diverted, not only on the peak flows used for project feasibility design.

The current Phase 4 of this study develops the feasibility design and cost estimates for the LPP that includes diversion (maximum discharge of approximately 20,000 cfs) combined with staging and storage immediately upstream of the diversion works. Some minor modifications to the alignment of the LPP diversion channel with respect to Phase 3, mostly on the north end (near Harwood, North Dakota), have been incorporated too. Because the project design concept now relies on diversion and storage, the work conducted in Phase 4 has been done using a revised, expanded (in its spatial domain) and improved HEC-RAS unsteady flow model (see Figure 2) for both project feasibility design and evaluation of impacts on flood levels upstream and downstream of the proposed diversion. This hydraulic model has been developed, calibrated, validated and used for cases of peak flows on the Red River of the North paired with coincidental events on the MN and ND tributaries (including the Wild Rice River, Sheyenne River, Maple River, Lower Rush River, Rush River, and some local drains and ditches). The model runs completed in Phase 4 include the analysis of Existing Conditions and With-Project for the four more recent larger flood events in Fargo-Moorhead (1997, 2006, 2009 and 2010) as well as for four hypothetical design floods along 325 river miles of the Red River of the North (10-percent, 2-percent, 1-percent and 0.2-percent chance synthetic hydrograph events). In addition, a separate HEC-RAS unsteady flow model has been developed and used for cases of peak flows on the ND tributaries and coincidental events on the Red River of the North to perform the feasibility design of the hydraulic structures required in the ND tributaries.

Following input from the USACE Project Delivery Team (PDT), the feasibility design and cost estimates developed for the FCP in Phase 3 have been maintained in Phase 4.

It is worthwhile highlighting that the feasibility design presented in this Phase 4 of the study has benefited significantly from the input received before and after submittal of the Phase 3 report (Consultant, 2010) and the Draft Environmental Impact Statement (EIS) published last year (USACE, 2010), including several comments and suggestions from:

- the USACE-PDT;
- the USACE Agency Technical Review (ATR);
- the USACE Independent External Peer Review (IEPR);
- the Fargo-Moorhead Metropolitan Technical Committee (FMMTC), with representatives from the City of Fargo, North Dakota; the City of Moorhead, Minnesota; Cass County, North Dakota; and Clay County, Minnesota;
- State and Federal Agencies, with representatives from the Minnesota Department of Natural Resources (MnDNR); the North Dakota Fish and Game Department (NDFGD); the North Dakota Department of Health – Division of Water Quality (NDDH-DWQ); the U.S. Fish and Wildlife Service (USFWS); the U.S. Federal Emergency Management Agency (FEMA); the U.S. Environmental Protection Agency (EPA); and the U.S. Geological Survey (USGS); and
- the general public.

The project concept designs presented here have been carried out to a feasibility level using general hydrologic, hydraulic, environmental, geotechnical, structural and civil design considerations. Given the constraints imposed by the amount and quality of the information available and the timeframe to complete the different phases of the feasibility study, the feasibility designs presented in this Phase 4 report are deemed sufficient to develop Class 3 cost estimates (see Appendix G) for congressional budgetary appropriation per USACE Engineer Regulation ER 1110-2-1302. However, it is acknowledged that additional investigations on aquatic ecosystems, fish passage, ice engineering, sediment transport and geomorphology (some of these investigations are already underway); future revisions and updates of the HEC-RAS unsteady flow models; physical modeling, and potentially additional 2D numerical modeling, of the more critical hydraulic structures (more critical for the overall functioning of the project); additional site specific information (e.g., soil borings, soil mechanics laboratory tests, field-scale pile driving tests) that become available in support of detailed geotechnical and structural engineering designs may result in changes to the proposed configuration, functioning and cost of some of the project features. These changes are not anticipated to result in an overall project cost increase beyond the cost contingency recommended in this feasibility study, unless there is a change in the scope or design criteria of the project.

The Phase 4 report has been organized in three tiers. The first one corresponds to this General Report, which is intended for a general audience, and it provides a description of the project design concept (i.e., the "big picture"), benefits and impacts, and cost estimates. This General Report also presents some specifics about the considerations used for determining the configuration, sizing and functioning of the main project features. The second tier corresponds to the main sections of Appendices A through G, which is intended for a more technical audience (including the different State and Federal Agencies), and it provides more specifics about the considerations used for the hydrologic, hydraulic, environmental, geotechnical, structural and civil design aspects and feasibility analysis of the proposed diversion works. The last tier corresponds to the Exhibits within some of the Appendices referred to above, which is intended for the specialists interested in learning all the details (including computational sheets) behind the feasibility design and cost estimates. The hard copies of the Phase 4 report are accompanied by DVD's with all the relevant electronic files, including those related to the HEC-RAS unsteady flow models for hydrology/hydraulics analysis and the MII files for cost estimates.

3.0 Summary of Project Alternatives and Features

3.1 General Design Considerations

As indicated above, the project proposed is intended to provide flood damage reduction up to the 0.2-percent chance flood event in the Red River of the North; that is, the 500-yr event in the Red River of the North is the design flood. Flood damage reduction has been defined in terms of target stages (or water surface elevations) in the Red River of the North at the USGS gage in Fargo. For reference, a stage of 30 feet corresponds to the start of major flooding in the City of Fargo, and the flood of record in the early spring of 2009 (about a 2-percent chance or 50-yr flood event) resulted in a stage near 41 feet. The target stages were set in Phase 3 and have served as the main reference for the Phase 4 feasibility design.

More specifically, the following main criteria have been used for feasibility design and evaluation of impacts on flood levels in Phase 4 of the study:

- to match the model Phase 3 With-Project stage in the Red River of the North at the USGS gage in Fargo within ±0.15 feet, such that the difference in project benefits between the Phase 4 and Phase 3 feasibility designs is less than 5 percent (email communication from USACE-PDT dated February 12, 2011);
- to eliminate adverse impacts on floods levels downstream of the diversion channel outlet at a point that is located upstream of the Canadian border, such that the area to be impacted is well defined and NEPA requirements are met. The elimination of impacts is considered as a difference in water surface elevations between model With-Project and Existing Conditions that is within ±0.04 feet. Because the tolerance used in HEC-RAS is 0.1 feet for water surface elevations in storage cells (i.e., model representation of floodplain), the precision of the model results is not greater than 0.1 feet. Therefore, the impacts on water surface elevations are rounded to the nearest 0.1 feet for flood management purposes, even though the model results are reported to the nearest 0.01 feet for transparency (email communication from USACE-PDT dated January 25, 2011); and
- to limit the amount of staging upstream of the diversion works (in order to accomplish the two criteria above) without the need for an engineered storage area that encroaches too close into the most populated centers within the protected area. It is an implicit goal to limit the extent of the area impacted, such that the number of structures affected with this Phase 4 feasibility design is less than that with the previous Phase 3 feasibility design (see general discussion in Section 1 above).

The project feasibility design has also considered measures for an effective routing of the Standard Project Flood (with a peak flow that is approximately 70 percent larger than that of the design flood) that does not compromise the integrity of the flood protection infrastructure, hence to avoid a catastrophic failure of the diversion system that could result in loss of life in the protected area. In addition, the design of the hydraulic structures in the ND tributaries have been based on the peak flows associated with the

0.2-percent chance flood event in the ND tributaries, which can be larger than the ones associated with the coincidental event to peaks in the Red River of the North.

Although it is not the goal of this General Report to present a comprehensive list of all the design criteria that have guided the feasibility design presented in the Phase 4 report (see Appendices C-F for details), some of the other key general design considerations follow below:

- passive over active (e.g., gated) flood control operational systems is preferred, except in the main line of flood protection at the south end of the diversion works, and possibly also at locations where backwater effects or interior flood control could require active systems;
- limiting the footprint of the diversion infrastructure is desired, to minimize direct and potential indirect environmental impacts;
- maintaining ice and debris flows in the rivers rather than in the diversion channel is preferred. In some cases, heating provisions may be needed to reduce the risk of freezing at critical diversion locations;
- avoiding operation of the diversion system during smaller floods is desired, to minimize impacts on the aquatic ecosystems and fisheries as well as on sediment transport and geomorphology of the affected riverine systems. In some cases, fishways may be desired to allow for fish migration during larger floods;
- designing infrastructure that meets geotechnical and structural engineering standards (from the USACE and industry) is required, to secure the physical integrity of the diversion works during the life of the project, given appropriate operation and maintenance practices; and
- developing flood protection infrastructure that is cost effective, to provide the level of flood damage reduction that is needed within the protected area.

3.2 HEC-RAS Unsteady Flow Model

The Existing Conditions HEC-RAS unsteady flow model was developed with sufficient detail to be used as a baseline for project feasibility design as well as benefit and impact analysis. It was calibrated based on the 2009 spring flood and the calibration was verified using the 2006, 1997, and 2010 historic spring flood events. The 10-percent, 2-percent, 1-percent, and 0.2-percent annual chance synthetic flood events were developed as the primary means to evaluate Existing Conditions, to assist with project feasibility design, and to analyze potential impacts from flood mitigation alternatives (LPP and FCP) being considered as part of this project.

The hydraulic analysis spans approximately 325 miles of the Red River of the North from near Abercrombie, North Dakota through Fargo, North Dakota and Moorhead, Minnesota to the downstream end at Drayton, North Dakota. The communities of Fargo and Moorhead are located approximately 453 river miles above the mouth of the Red River of the North at Lake Winnipeg, Manitoba. The river model geometry is highlighted in Figure 2. It includes the Red River of the North main stem and several tributaries. The Phase 2 study area originally extended north only to River Mile 375 at Halstad, MN. When it was found that downstream impacts could not be fully defined (zero impact location) within the original study extents, the model was first extended to River Mile 316 near Thompson, North Dakota (Phase 3), and then to River Mile 198 at Drayton (Phase 4). It has also been extended upstream on the Red River of the North to near Abercrombie, North Dakota at approximately River Mile 524. The model was also extended farther upstream on the Sheyenne and Maple Rivers to better define the breakouts and flow distribution on the western side of the project.

The HEC-RAS unsteady flow model geometry was developed by combining geometry from existing unsteady and steady state models with new geometry developed for this project. The combined geometry includes approximately 880 storage areas and 2935 cross sections. The cross sections were created using a hybrid of LiDAR elevation data and surveyed channel bathymetry. They were extended upstream on the Red River of the North and upstream on most of the tributaries to locations with input data from USGS stream gages. The storage areas and storage area connections were developed using LiDAR elevation data and field survey. Hydraulic structures (bridges and culverts) were created with survey data or were estimated depending on their location. The source and quality of data must be considered when using the model for analysis and when reviewing results. Appendix B provides additional documentation on the geometry sources and quality.

The HEC-RAS unsteady flow model was calibrated to the 2009 spring flood event using high water mark and gage data obtained from city, county, and federal agencies. This flood event was chosen for the calibration event because it was the flood of record and was well documented by high water marks and stream gage data. The model was generally calibrated to a tolerance of within one-half foot of the 2009 spring flood high water marks, which matches FEMA's criteria for hydraulic model calibration. The model was verified using the spring floods of 2006 (fifth highest), 1997 (second highest), and 2010 (sixth highest). Temporary flood protection measures (levees) specific to each flood event were added to the respective model geometry. The temporary flood protection measures were removed for the synthetic design events. Calibration included adjusting model geometry parameters such as Manning's "n" values, ineffective flow limits, overbank reach lengths, evaluating different model representations of flow through the floodplain, and verifying the quality of observed inflow data.

Model inflows for the HEC-RAS unsteady flow model consist of nearly 80 inflow hydrographs. Some originate at USGS gage locations, others are un-gaged local inflows. The hydrograph development procedures used for historic events and synthetic events are similar. An inflow hydrograph was inserted at the upper boundary condition of each river reach and intermediate hydrographs were added as local inflow to help match the target hydrographs on the Red River of the North. USGS stream gage hydrographs (daily data) were inserted at the upstream boundary condition of each stream for historic events. Synthetic design events used a balanced hydrograph at the upstream end of the Red River of the North and the 2006 USGS stream gage hydrograph with a specified multiplier on each of the upstream ends of the tributaries. The typical multipliers vary depending on flood event, with some additional variation by watershed. The 10-percent chance multiplier is 0.65, the 2-percent chance multiplier is 1.40, the 1-percent chance multiplier is 1.80, and the 0.2-percent chance multiplier is 2.30.

Local inflow hydrographs were estimated to supplement the modeled hydrographs between calibration locations in the Red River of the North. The model was executed with known upstream boundary condition hydrographs (historic or synthetic). The flood hydrographs were then routed downstream to the next match-to location in the HEC-RAS unsteady flow model. These are stream gages for historic events and balanced hydrograph locations for synthetic events. The difference between the routed hydrograph and the observed (gage or balanced hydrograph) is the required local inflow hydrograph. This hydrograph is adjusted for routing and is spatially distributed amongst the local un-gaged drainage areas. Therefore, the model runs for historic events and synthetic events includes upstream end hydrographs and local inflow hydrographs. Less detail was placed on the model geometry and inflows downstream of Thompson. The tributaries in this model reach were not modeled and all synthetic inflow hydrographs were created by spatially distributing all local inflows across the contributing drainage area.

The With-Project HEC-RAS unsteady flow model was developed based on the Existing Conditions HEC-RAS unsteady flow model described above, and it included the modification of the storage cells and lateral structures (i.e., model representation of the floodplain) along the diversion alignment to allow for the diversion channel and hydraulic structures geometry to be merged with the Existing Conditions model. Utilizing GIS and HEC-RAS capabilities, a corridor of sufficient width to accommodate the diversion channel and spoil banks was cut through the storage areas included in the model. Some storage areas were split into two smaller areas and some resulted in one smaller storage area. After this was completed, the storage area connections were adjusted to reflect the changes. In addition, the upstream staging and storage areas identified for this project feasibility design were incorporated into the model along with the associated connections.

Due to the amount of time required for the unsteady state simulations to be completed, utilizing the initial HEC-RAS unsteady flow models for optimizing the diversion channel design would not have been efficient, especially considering the timeline for completion of this phase of the feasibility study. As the unsteady state baseline models were being modified, a steady state model was created to generate an initial diversion design that could be inserted into the unsteady state model for further refinement. However, the feasibility design as well as the evaluation of impacts on flood levels upstream and downstream of the project that is presented in this Phase 4 report reflects the hydrologic and hydraulic modeling using the With-Project HEC-RAS unsteady flow model. This modeling incorporates the proposed configuration of the diversion channel (see Appendix D) and primary hydraulic structures (see Appendix F).

3.3 Locally Preferred Plan (LPP)

3.3.1 Summary of Project Features

The main features consist of the LPP diversion channel, Storage Area 1 and tie-back levees, the primary inlet structure, the control and diversion structures at the Red River of the North and ND tributaries, and the outlet structure (see Figure 1). Additionally, the LPP includes 19 highway bridges and 4 railroad bridges that cross the diversion channel.

The LPP diversion channel starts approximately 9 river miles south of the confluence of the Red River of the North and Wild Rice River, leads west toward the existing Horace to West Fargo diversion, then north around the Cities of Fargo and West Fargo, and ultimately re-enters the Red River of the North 8 river miles north of its confluence with the Sheyenne River. The alignment is approximately 36 miles long. The diversion channel geometry was determined based on required conveyance capacity, which increases in the downstream direction to accommodate diversion from the ND tributaries and numerous legal drains (see Figures 5-8), and then modified based on geotechnical slope stability analysis at various reaches along the diversion. Two other goals considered were first to result in a 100-yr (1-percent chance) water surface elevation in the LPP diversion channel that is mostly below existing ground for the reach between the inlet structure and the Maple River crossing, and second to reduce (compared to Phase 3) the volume of excavation of Brenna clays (see Figure 3). For the main reach downstream of the primary inlet structure, the LPP diversion channel would have an earth excavated trapezoidal cross section (except at the location of hydraulic structures), bottom width of 250 feet, and sideslopes of 7H:1V above and below benches of varying width. A low flow pilot channel would run along the bottom of this reach, and erosion protection at the toe of the main channel sideslopes would be provided. Upstream of the primary inlet structure, the diversion channel would have a smaller cross section and a longitudinal slope that follows natural topography, as it is mostly intended for local drainage and hydraulic conveyance during smaller flood events, not for controlling flows diverted downstream during the larger flood events.

The main hydraulic structures controlling the flows passing into the protected area during the larger flood events are the control structures proposed on the Red River of the North and Wild Rice River, with effective flow widths of 150 feet and 60 feet, respectively. These gated structures would be operated only when the forecasted peak flow of the incoming hydrograph in the Red River of the North at the USGS gage in Fargo is greater than 9600 cfs, which has a frequency of approximately 2 days per year on the average (note: it does not happen every year for 2 days). Otherwise, the structure resembles a bridge (with fully open gates). Secondary by-pass channels for fish passage have been included at both of these structures. The main line of flood protection at the south end of the project would be completed with Storage Area 1 and the primary diversion inlet structure. Storage Area 1 is a 4360-acre area on the north side of the LPP diversion channel between the Wild Rice River and the Sheyenne River, which will be formed by nearly 12 miles of embankments. Storage Area 1, combined with staging in the floodplain (see Figure 4), will eliminate impacts on flood levels downstream of the diversion channel outlet. The diversion inlet structure is a passive weir (no gates or other regulation controls), with an effective flow width of 90 feet. Although the maximum diversion flows at this location are smaller in Phase 4 than in Phase 3, the increased headwater and greater vertical drop have warranted a change to an Ogee-type concrete spillway.

The other main hydraulic structures include three types at different locations along the LPP diversion channel. The first type is located at the Sheyenne River and Maple River. It would include a combination of a transition to a reinforced concrete rectangular cross section in the LPP diversion channel, with a total width of 250 feet; a reinforced concrete aqueduct crossing of the LPP diversion channel transition, with approximate dimensions 50 feet wide and 20 feet high, which would include roughness elements to provide flow complexity patterns and a low flow channel to avoid freezing during winter; and a sheetpile-rockfill protected spillway (similar concept to that used at the inlet structure of the West Fargo diversion in the Sheyenne River), which would be approximately 300 feet wide. The crest elevation of the spillway would be set at the 2-yr water surface elevation associated with the peak flow in the tributary (it will be the sum of the 2-yr peak flows in the Maple River, Lower Rush River and Rush River at the Maple River), such that up to this event the entire tributary flow would be passed through the aqueduct into the protected area, but for larger events most of the tributary flow would be diverted into LPP diversion channel. The second type is located at the Lower Rush River and Rush River. It would include a combination of a vertical drop (this is also proposed for Drain 14), with a total width of 60 feet and 100 feet at the Lower Rush River and Rush River, respectively; and a fishway consisting of 40 feet wide riffle-pool sequences, that would extend from the tributary channel down to the low flow pilot channel of the LPP diversion channel. The entire tributary would be diverted into the LPP diversion channel during all flow conditions, and to compensate for the loss of approximately 5.5 miles of existing tributary channels (the channel was built by the USACE several decades ago to convey the natural overland flow pattern in this area), the lower 11 miles of the low flow pilot channel in the LPP diversion channel would be allowed to meander. The last type is the outlet structure, which would be an Ogee-type concrete spillway, with an effective flow width of 250 feet. Although the maximum diversion flows at this location are smaller in Phase 4 than in Phase 3, the significantly greater vertical drop have warranted the change in the concept feasibility design at this location.

3.3.2 Upstream Staging/Storage and Downstream Impacts – Historic Events

As indicated above in Section 2, work completed in Phase 4 includes the modeling of Existing Conditions and With-Project (see Figures 3-14) for the four more recent larger flood events in Fargo-Moorhead (1997, 2006, 2009 and 2010). Although these model runs are not intended for project feasibility design or for flood damage reduction evaluation, they provide two very tangible benefits. First, they offer the possibility to better communicate the project impacts to all stakeholders and the general public because they can relate to how the project would change the conditions that were experienced during the recent larger flood events. It is more reasonable to anticipate that this information could be conveyed in a clear way, as there is no need to explain concepts that are not familiar to a layperson, like the meaning of balanced hydrographs or return periods. However, the caveat to highlight is that the model Existing Conditions for historic and synthetic event comparisons do not include the emergency protection measures that were in place during these historic events. The second benefit of having conducted these model runs is that they allow estimation of project upstream staging/storage and downstream impacts without having to assume that the magnitude and timing of tributary flows affect the magnitude and timing of flooding downstream; this is better captured with looking at four historic events versus the synthetic event analysis.

In general, the comparison of model Existing Conditions and model With-Project for these four historic flood events sheds lights on the magnitude of upstream staging/storage that is required to eliminate impacts on flood levels downstream of the diversion outlet; for more details on the model results, see Table 1. Maps that show the Existing Conditions and With-Project floodplain are included in Appendix C.

The review of the model Existing Conditions shows that the peak stage in the Red River of the North at Fargo was near 40 feet during the historic 1997 and 2009 flood events, whereas the peak stage at this location was near 37 feet during the historic 2006 and 2010 flood events. For additional reference, the first two larger flood events were close to a 2-percent chance event in Fargo, whereas the other two were close to a 5-percent chance event in Fargo. For the two larger historic flood events, if the water levels upstream of the diversion works are staged from model Existing Conditions 912-914 feet to model With-Project 922 feet, then downstream impacts could be eliminated before reaching the downstream end of the model at Drayton. For the 2006 and 2010 events, staging would be from model Existing Conditions 910-911 feet to model With-Project 919 feet in order to eliminate downstream impacts. Although the relative staging (difference in water surface elevations for model With-Project and Existing Conditions immediately upstream of the diversion works) is similar for the four events, it appears that the ultimate water surface elevation upstream of the diversion works is the one dictating the downstream impacts. In other words, the additional volume of approximately 75,000 acre-feet that can be staged and stored between 919 feet (approximately 125,000 acre-feet) and 922 feet (approximately 200,000 acre-feet) explains the elimination of downstream impacts for the two larger historic flood events. And this occurs even when the With-Project stage at the Red River of the North in Fargo is very similar for the four historic flood events (within a range of 1.5 feet). All of this suggests that in order to eliminate downstream impacts, upstream staging and storage to water surface elevations around 922 feet (which includes over 50,000 acre-feet in Storage Area 1) would be required, and more importantly, that the diversion works need to be operated not only based on peak flows but primarily based on total hydrograph volumes, in particular those during the rising limb of the hydrograph.

3.3.3 Upstream Staging/Storage and Downstream Impacts – Design Floods

Work completed in Phase 4 also includes the modeling of Existing Conditions and With-Project for four synthetic events (0.2-percent, 1-percent, 2-percent, and 10-percent chance design floods), which have been used for project feasibility design, flood damage reduction evaluation and impacts assessment on flood levels upstream and downstream of the proposed diversion. It is important to clarify here that the models referred to above and the discussion in this section of the General Report correspond to peak flows on the

Red River of the North paired with coincidental events on the ND tributaries. For project feasibility design, separate models have been created for cases of peak flows on the ND tributaries paired with coincidental events on the Red River of the North in order to appropriately size the hydraulic structures in the ND tributaries for extreme events in these rivers.

The summary results of model Existing Conditions (which do not include emergency protection measures that were in place during the larger historic events, as indicated above) and model With-Project at gaged locations along the Red River of the North are presented in Table 2. Maps that show the Existing Conditions and With-Project floodplain are included in Appendix C, and a condensed version of areas of inundation upstream and downstream of the project is provided in Figures 15-22.

The review of the model Existing Conditions shows that the flows immediately upstream of the diversion works in the Red River of the North main conveyance channel vary between approximately 10,300 and 28,600 cfs from the 10-percent to the 0.2-percent chance design flood. Accordingly, the model Existing Conditions flows and stage in the Red River of the North at the Fargo gage (which include the contribution of the Wild Rice River) vary between approximately 17,000 and 61,700 cfs and between approximately 34.6 and 43.1 feet, respectively, from the 10-percent to the 0.2-percent chance design flood. For the two larger synthetic events (i.e., the 0.2-percent and 1-percent chance design floods), if the water levels upstream of the diversion works are staged from model Existing Conditions 915-916 feet to model With-Project 922-923 feet, then downstream impacts could be eliminated before reaching the downstream end of the model at Drayton and the model With-Project stage in the Red River of the North at the Fargo gage is within ±0.15 feet of the Phase 3 values. This range of staged water surface elevation upstream of the diversion works (which translates into over 50,000 acre-feet in Storage Area 1, and a total volume staged/stored of approximately 200,000 acre-feet), is similar to that obtained for the two larger historic flood events in the Red River of the North at Fargo (i.e., 2009 and 1997), and it reinforces the suggestion that in order to eliminate downstream impacts for extreme floods, upstream staging and storage to water surface elevations near 922 feet would be required.

When looking at the magnitude of the relative staging upstream required to eliminate downstream impacts for the smallest synthetic event analyzed (i.e., the 10-percent chance design flood), from water surface elevation for model Existing Conditions 908 feet to water surface elevation for model With-Project 916 feet, it becomes clear that the diversion works need to be operated not only based on peak flows but primarily based on total hydrograph volumes, in particular during the rising limb of the hydrograph. That is, the overall performance of the diversion works (to meet the three main design criteria listed above) depends on the trade between storage (through upstream staging or Storage Area 1) and release (through the diversion channel or the control structure on the Red River of the North) of the incoming flood flows and volumes during the rising limb of the hydrograph. This in turn may imply that, as found during several trial runs of the HEC-RAS unsteady flow model for With-Project, allowing more water to pass into the protected area through the control structure on the Red River of the North does not necessarily help to eliminate impacts downstream if the timing of this release is similar to the timing of the peak flows and flood volumes being conveyed through the diversion channel. Indeed, it was found that the best operational scheme of the gates in the control structure on the Red River of the North (the best to eliminate downstream impacts without increasing the upstream staging) was the one that decouple the peak flows and flood volumes conveyed through the diversion channel from those passing into the protected side. Thus, for all synthetic events, the operational scheme of these gates proposed at this feasibility level is to progressively close them during the rising limb until approaching (but before) the peak of the incoming hydrograph, keep them at their lowest position until the peak flows and flood volumes in the diversion channel have exited the diversion, and then progressively open the gates to reach the Phase 3 stage in the Red River of the North at the Fargo gage.

3.4 Federally Comparable Plan (FCP)

3.4.1 Summary of Project Features

The FCP diversion alternative for the Phase 4 feasibility study is the same as the one presented in the Phase 3 report. The main features consist of a control structure on the Red River of the North, the diversion channel, and the outlet structure for the diversion channel. The FCP diversion channel starts approximately one mile north of the confluence of the Red River of the North and Wild Rice River, extends north around the Cities of Moorhead and Dilworth and ultimately re-enters the Red River of the North near its confluence with the Sheyenne River. The alignment is approximately 25 miles long. In addition to the main diversion channel, this alignment requires additional channels upstream of the Red River control structure to prevent stage increases upstream of the project along the Red River of the North and Wild Rice River. A supplementary extension channel parallels the Red River of the North upstream of the entrance to the diversion channel to allow for additional capacity to offset blockage of the breakouts to Cass County Drains 27 and 53. This secondary FCP extension channel is approximately 3 miles long and has a 215 foot bottom width. A second, shorter channel, the Wild Rice Breakout Channel, was added near the intersection of I-29 and Cass County Highway 16. This channel, which is less than one mile long and crosses under I-29, will convey water across I-29 that would have naturally broken out to Cass County Drain 27 and has a 50 foot bottom width. Additionally, the FCP includes 20 roadway bridges and 4 railroad bridges that cross the diversion channel.

The diversion channel consists of an inlet weir, which consists of a passive (i.e., no gates or movable parts) compound weir with a crest elevation approximately one half foot above the water surface elevation for the 3.6-yr event (9,600 cfs) from the steady state hydrology. The diversion channel geometry was determined based on hydraulic capacity and then modified based on geotechnical analysis at various reaches along the diversion. The feasibility design sections for the FCP diversion channel include a 10H:1V slope near the bottom below a bench of varying width. Above the bench, the sideslope is 7H:1V up to existing ground and the spoil piles are offset 50 feet from the top of the slope. The bottom width of the FCP diversion channel varies from 225 feet at the downstream end to 400 feet beginning near Clay County Highway 22. A low flow pilot channel runs along the bottom of the diversion channel.

For the FCP, the control structure located on the Red River of the North is similar to the one proposed for the LPP. However, in this case the design goal for this structure is to avoid increasing water surface elevations upstream in the Red River of the North, while minimizing (not necessarily eliminating) impacts on flood levels downstream of the diversion. The outlet of the FCP diversion channel into the Red River of the North consists of riprap covering approximately 300 feet of the downstream end of the diversion channel.

3.4.2 Downstream Impacts – Historic Events

Similar to the LPP, Phase 4 includes the modeling of Existing Conditions and With-Project (FCP) for the historic 1997, 2006, 2009, and 2010 spring floods to determine the downstream impacts. These impacts are related to the loss of floodplain storage and changes to timing as a result of the flows conveyed through the diversion channel. For the FCP downstream impact analysis, the emergency protection measures that were in place during these historic event calibrations/verifications were not included. The FCP diversion channel from the Phase 3 design was incorporated into the Phase 4 HEC-RAS unsteady flow model. The With-Project water surface profiles were then compared to the Existing Conditions water surface profile to quantify the project impacts. The downstream impact tables for the FCP for the historic 1997, 2006, 2009, and 2010 spring flood events are presented in Appendix C, and a summary is provided in Table 3.

In summary, the downstream impacts begin just downstream from the diversion channel outlet and gradually attenuate downstream. Two factors that contribute to localized increases in downstream impacts are the floodplain width as well as timing of tributaries that enter the Red River of the North downstream from the diversion channel outlet. Maps that show the existing conditions and with-project floodplain are included in Appendix C. For the historic 1997 flood event, the maximum downstream impacts occur between Halstad, MN and Thompson, ND (0.63 feet) while the minimum impact occurs between Grand Forks, ND and Oslo, MN (0.03 feet). For the historic 2006 flood event, the maximum downstream impacts occur between Fargo, ND and Halstad, MN (0.37 feet) while the minimum impact occurs between Grand Forks, ND and Oslo, MN (0.01 feet). For the historic 2009 flood event, the maximum downstream impacts occur between Halstad, MN and Thompson, ND (1.12 feet) while the minimum impact occurs between Oslo, MN and Drayton, ND (0.08 feet). For the historic 2010 flood event, the maximum downstream impacts occur between Halstad, MN and Thompson, ND (0.37 feet) while the minimum impact occurs between Grand Forks, ND and Oslo, MN (0.02 feet).

3.4.3 Downstream Impacts – Design Floods

Phase 4 also includes the modeling of Existing Conditions and With-Project (FCP) for four synthetic events (0.2-, 1-, 2-, and 10-percent chance design floods) to determine the downstream impacts. These impacts are related to the loss of floodplain storage and changes to timing as a result of the diversion channel. The FCP diversion channel from the Phase 3 design was incorporated into the Phase 4 HEC-RAS unsteady flow model. The With-Project water surface profiles were then compared to the Existing Conditions water surface profile to quantify the project impacts. The downstream impact tables for the FCP for the 0.2-, 1-, 2-, and 10-percent chance design flood events are presented in Appendix C, and a summary is provided in Table 4.

In summary, the downstream impacts begin just downstream from the diversion channel outlet and gradually attenuate downstream. Two factors that contribute to localized increases in downstream impacts are the floodplain width as well as timing of tributaries that enter the Red River of the North downstream from the diversion channel outlet. Maps that show the Existing Conditions and With-Project floodplain are included in Appendix C. For the 0.2-percent chance design flood, the maximum downstream impacts occur between Thompson, ND and Grand Forks, ND (0.45 feet) while the minimum impact occurs between Grand Forks, ND and Oslo, MN (0.06 feet). For the 1-percent chance design flood, the maximum downstream impacts occur between Halstad, MN and Thompson, ND (1.23 feet) while the minimum impact occurs between Oslo, MN and Drayton, ND (0.05 feet). For the 2-percent chance design flood, the maximum downstream impacts occur between Halstad, MN and Thompson, ND (1.01 feet) while the minimum impact occurs between Grand Forks, ND and Oslo, MN (0.02 feet). For the 10-percent chance design flood, the maximum downstream impacts occur between Fargo, ND and Halstad, MN (0.45 feet) while the minimum impact occurs between Oslo, MN and Drayton, ND (0.03 feet).

4.0 Project Costs

Phase 4 feasibility costs for the LPP have been completed. These cost estimates have been developed to the same Class 3 level of estimate as in Phase 3. All estimates are completed using the MII cost estimating program, USACE manual guidance and coordination with the USACE-PDT. Cost estimates, documentation and discussion included in this Phase 4 report are intended to provide background information for feasibility cost risk assessment and analysis purposes by the USACE, and to be finalized and used by the USACE for congressional budgetary appropriation of the selected diversion alternative.

Selected project features incorporated in the cost estimates presented by the Consultant in this Phase 4 report include (numbering shown refers to categories presented in the USACE total project cost summary):

- 02 Relocations (Roadway Bridges and Road Raises only);
- 08 Roads, Railroads and Bridges (costs to reconstruct railway facilities in the vicinity of the project);
- 09 Channels and Canals (costs to construct the diversion channel facilities, hydraulic structures and associated site work); and
- 11 Levees and Floodwalls (costs to construct tie-back levees, storage area(s) and floodwalls).

Items are intentionally excluded from the cost estimates presented in this Phase 4 report, as coordinated with the USACE-PDT, but they are required for a complete feasibility estimate of the Total Project Cost Summary. These items will be estimated by the USACE-PDT, or others. These items include:

- 01 Lands and Damages
- 02 Relocations (except for Roadway Bridges and Roadway Raises)
- 06 Fish and Wildlife Facilities (except for fishways on Red River of the North, Wild Rice River, Lower Rush River and Rush River, which are included in 09 Channels and Canals)
- 14 Recreation Facilities
- 30 Planning, Engineering and Design (PED)
- 31 Construction Management (CM)
- Other additions as determined by the USACE, including temporal escalation factors, HTRW, final contingency assignment upon cost risk analysis, environmental mitigation, cultural resources work, etc.

The methodology and summary tables of the cost estimates for the LPP and FCP that are presented in Table 5 and Table 6, respectively, correspond to the February 28, 2011 submittal of the Consultant's Report. Revisions to the cost estimates following USACE-ATR dated April 15, 2011 have been fully addressed in Appendix L of the Feasibility Report by the USACE-PDT. For completeness, the revised summary cost estimates for the LPP and FCP are presented in Table 7 and Table 8, respectively of this April 19, 2011 submittal of the Consultant's Report. It is important to note that a contingency has been intentionally omitted from the cost estimates in Tables 7 and 8, as the contingency will be determined by the USACE-PDT after the Cost Schedule Risk Analysis (CSRA) currently underway is completed. Tables 5 and 6 present the contingencies recommended by the Consultant.

The discussion below is based on contract costs (i.e., without including a contingency) and the cost estimates presented in Tables 7 and 8 (i.e., after incorporating the changes recommended by the USACE-ATR dated April 15, 2011).

In the previous Phase 3 of this feasibility study (including revisions to the FCP cost estimates dated August 18, 2010), the construction costs (not including contingencies) developed by the Consultant for selected project features (within the categories listed above) of the LPP and FCP were $752 Million and $650 Million, respectively. In the current Phase 4 of this feasibility study, the construction costs (not including contingencies) for selected project features (within the categories listed above) of the LPP and FCP are $870 Million and $690 Million, respectively. All of these costs correspond to 2010 US Dollars and do not include temporal escalation factors (these costs were later added by USACE in Phase 3, and will be again added by USACE in Phase 4). Summary tables of the feasibility cost estimates for the selected project features referred to above of the LPP and FCP are presented in Tables 7 and 8, respectively. These feasibility cost estimates for the two diversion alternatives are submitted to the USACE-PDT in the form of two (2) digital MII files, and a detailed description of the assumptions used to develop quantities and cost estimates (including work analysis, contractor assumptions, unit prices, contingencies and breakdown of labor, equipment and materials) are provided in Appendix G.

The main differences between the Phase 3 and Phase 4 feasibility cost estimates (not including contingencies) for the LPP are as follow:

- there is an increase of approximately $39 Million in the cost of the Roadway Bridges, Road Raises & Local Road Construction from Phase 3 to Phase 4, which is mainly driven by road raises in the area subject to staging immediately south of the diversion works;
- there is a reduction of approximately $80 Million in the cost of the Diversion Channel from Phase 3 to Phase 4, which is mainly driven by a smaller cross section of the diversion channel, and also the fact that approximately 3.5 miles of diversion channel have been associated with the cost of the hydraulic structures in Phase 4 (we did this to allow for appropriate grading from the hydraulic structures to the main section of the diversion channel);
- there is an increase of approximately $6.3 Million in the cost of the Control Structure in the Red River of the North from Phase 3 to Phase 4, which is mainly driven by the requirement of a taller structure due to staging immediately south of the diversion works;
- there is an increase of approximately $0.9 Million in the combined cost of the Control Structure in the Wild Rice River, East Weir and the primary Diversion Inlet Structure from Phase 3 to Phase 4, which results from the trade between a taller structure in the Wild Rice River due to staging immediately south of the diversion works, a more robust and expensive Inlet Structure, a significantly

reduced scope and cost of the Phase 3 East Weir, and the elimination of the Phase 3 West Weir;

- there is an increase of approximately $11 Million in the combined cost of the Hydraulic Structures at the Sheyenne River and Maple River from Phase 3 to Phase 4, which is mainly driven by the inclusion of longer reaches (in Phase 4) of the main diversion channel that are associated with the cost of these structures, and longer spillways due to lower water surface elevations in these tributaries (after revisions with the unsteady flow model);
- there is an increase of approximately $7.9 Million in the combined cost of the Hydraulic Structure at Drain 14 and the Large Drain Structure from Phase 3 to Phase 4, which is mainly driven by the need for a very large concrete drop structure at Drain 14 in order to minimize impacts to the floodplain to the west of the diversion channel (after revisions with the unsteady flow model). However, one possibility is to construct a less expensive drop structure to convey low to average flows into the diversion channel at the current Drain 14 crossing location combined with a flood flow channel at a higher elevation to convey high flows north to the proposed hydraulic structures at the Maple River;
- there is an increase of approximately $1.8 Million in the combined cost of the Hydraulic Structures at the Lower Rush River and Rush River from Phase 3 to Phase 4. However, at both locations there is a real opportunity for further evaluating the design of the fishway to operate during all flow conditions, therefore eliminating the need for the very large concrete drop structures that account for a very significant fraction of the total cost (of approximately $35 Million) for the structures at these two sites. Alternatively, the structure at the Lower Rush River could be completely eliminated by routing the flows of this tributary at existing grade along the west side of the diversion channel all the way north to the Rush River, where a single combined drop structure and fish passage could be constructed;
- there is an increase of approximately $20 Million in the cost of the Outlet Structure from Phase 3 to Phase 4, which is mainly driven by the change in feasibility design from the Phase 3 rip rap protection of the downstream 300 feet of the diversion channel to a Phase 4 Ogee-type concrete spillway due to the significant increase in drop between the diversion channel invert at the outlet and the Red River thalweg elevation at that location. However, additional detailed studies could demonstrate that when high flows (driven by either peaks in the Red River of the North or peaks in the ND tributaries) are discharging through this structure, the flows and related water surface elevations in the Red River of the North are also high, so a smaller drop or shorter stilling basin could be justified, in both cases reducing the cost; and
- there is an increase of approximately $108 Million in the cost of the Levees and Floodwalls from Phase 3 to Phase 4, which is mainly driven by the requirement of taller and longer levees (including Storage Area 1 embankments, inlet and outlet structures) due to staging immediately south of the diversion works, and the new explicit requirement in Phase 4 to deal with routing of the Standard Project Flood.

Tables

TABLE 1: Summary HEC-RAS Unsteady Flow Model Results for Historic Floods - Locally Preferred Plan

North Dakota Diversion (LPP) - 1997 Event (No Protection)							
Location	Station	Existing No Protection		ND Diversion (LPP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	801.95	123,404	801.94	123,251	-0.01	-153
Oslo Gage	1416287	813.29	124,661	813.30	124,735	0.01	74
Minimum Impact Location	1555329	833.59	119,246	833.60	119,281	0.01	35
Grand Forks Gage	1558518	834.04	119,103	834.05	119,142	0.01	39
Thompson Gage	1667877	847.29	78,351	847.43	79,439	0.14	1,088
Maximum Impact Location (Nielsville)	1829877	860.86	71,728	861.11	72,925	0.25	1,197
Halstad Gage	1981580	868.65	64,821	868.78	66,780	0.13	1,959
Fargo Gage (13th Ave S, 12th Ave S)	2388223	902.42 (39.68*)	27,574	893.11 (30.37*)	9,968	-9.31	-17,606
US Diversion**	2531315	911.89	13,686	921.60	9,530	9.71	-4,156
Hickson Gage**	2563754	913.85	13,729	921.63	13,235	7.78	-494
Abercrombie**	2764835	931.08	13,995	931.36	13,995	0.28	0

North Dakota Diversion (LPP) - 2006 Event (No Protection)							
Location	Station	Existing No Protection		ND Diversion (LPP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	799.44	78,252	799.46	78,666	0.02	414
Oslo Gage	1416287	811.58	74,550	811.61	75,093	0.03	543
Minimum Impact Location	1443147	813.86	75,635	813.88	76,312	0.02	677
Grand Forks Gage	1558518	828.63	72,782	828.72	73,387	0.09	605
Thompson Gage	1667877	840.63	52,499	840.84	53,273	0.21	775
Maximum Impact Location	1749702	848.33	52,262	848.59	53,030	0.26	768
Halstad Gage	1981580	866.64	43,060	866.70	43,552	0.06	492
Fargo Gage (13th Ave S, 12th Ave S)	2388223	899.57 (36.83*)	21,028	891.96 (29.22*)	10,109	-7.61	-10,919
US Diversion**	2531315	910.60	14,053	918.72	9,530	8.12	-4,523
Hickson Gage**	2563754	913.11	14,313	918.90	14,362	5.79	49
Abercrombie**	2764835	931.58	15,027	931.74	15,027	0.16	0

North Dakota Diversion (LPP) - 2009 Event (No Protection)							
Location	Station	Existing No Protection		ND Diversion (LPP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	799.85	85,308	799.84	85,166	-0.01	-143
Minimum Impact Location	1345544	805.87	91,028	805.88	90,929	0.01	-99
Oslo Gage	1416287	812.02	85,672	812.04	84,367	0.02	-1,304
Grand Forks Gage	1558518	829.33	77,165	829.39	77,550	0.06	385
Maximum Impact Location	1561353	830.20	63,468	830.28	63,506	0.08	38
Thompson Gage	1667877	843.05	61,510	843.07	61,577	0.02	67
Halstad Gage	1981580	867.60	55,176	867.56	54,910	-0.04	-266
Fargo Gage (13th Ave S, 12th Ave S)	2388223	902.66 (39.92*)	29,234	893.46 (30.72*)	11,561	-9.20	-17,674
US Diversion**	2531315	914.24	23,639	921.62	10,897	7.38	-12,742
Hickson Gage**	2563754	917.76	24,393	921.64	24,562	3.88	170
Abercrombie**	2764835	937.51	28,176	937.59	28,176	0.08	0

North Dakota Diversion (LPP) - 2011 Event (No Protection)							
Location	Station	Existing No Protection		ND Diversion (LPP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	798.71	65,928	798.72	66,106	0.01	177
Minimum Impact Location	1327581	803.80	66,011	803.81	65,808	0.01	-203
Oslo Gage	1416287	811.09	67,101	811.07	66,850	-0.02	-251
Grand Forks Gage	1558518	827.23	63,406	827.19	63,172	-0.04	-235
Thompson Gage	1667877	840.28	52,023	840.44	52,694	0.16	672
Halstad Gage	1981580	866.55	42,389	866.70	43,585	0.15	1,196
Maximum Impact Location (Hendrum)	2038409	870.62	38,264	870.86	39,350	0.24	1,085
Fargo Gage (13th Ave S, 12th Ave S)	2388223	899.77 (37.03*)	21,481	892.38 (29.64*)	10,291	-7.39	-11,190
US Diversion**	2531315	910.17	12,352	918.90	8,623	8.73	-3,729
Hickson Gage**	2563754	912.23	12,677	918.98	12,686	6.75	8
Abercrombie**	2764835	930.57	13,236	930.74	13,236	0.17	0

* Flood stage at USGS Gaging Station 05054000, Fargo, ND

** Discharge does not include flow conveyed in the floodplain outside the main conveyance channel of the Red River

TABLE 2: Summary HEC-RAS Unsteady Flow Model Results for Design Floods - Locally Preferred Plan

North Dakota Diversion (LPP) - 0.2% Chance Event (No Protection)							
Location	Station	Existing No Protection		ND Diversion (LPP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	804.12	168,364	804.23	171,002	0.11	2,638
Minimum Impact Location	1410241	812.15	152,872	812.19	156,165	0.04	3,294
Oslo Gage	1416287	813.88	152,851	813.93	156,084	0.05	3,232
Grand Forks Gage	1558518	836.36	146,225	836.58	149,112	0.22	2,887
Maximum Impact Location	1561353	838.53	102,444	838.80	102,054	0.27	-390
Thompson Gage	1667877	850.69	112,422	850.64	111,394	-0.05	-1,027
Halstad Gage	1981580	871.54	101,754	871.32	92,746	-0.22	-9,007
Fargo Gage (13th Ave S, 12th Ave S)	2388223	905.8 (43.06*)	61,717	902.77 (40.03*)	29,865	-3.03	-31,852
US Diversion**	2531315	915.94	28,577	922.44	27,846	6.50	-731
Hickson Gage**	2563754	919.69	35,636	922.54	32,491	2.85	-3,145
Abercrombie**	2764835	940.90	44,308	940.91	44,308	0.01	0
North Dakota Diversion (LPP) - 1% Chance Event (No Protection)							
Location	Station	Existing No Protection		ND Diversion (LPP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	801.73	119,255	801.81	120,751	0.08	1,496
Minimum Impact Location	1410241	811.47	113,625	811.51	115,682	0.04	2,057
Oslo Gage	1416287	813.01	113,556	813.07	115,628	0.06	2,071
Grand Forks Gage	1558518	832.97	107,980	833.21	110,497	0.24	2,517
Maximum Impact Location	1573768	835.27	80,735	835.56	80,686	0.29	-49
Thompson Gage	1667877	847.35	82,926	847.39	82,608	0.04	-317
Halstad Gage	1981580	869.09	71,581	869.03	70,992	-0.06	-589
Fargo Gage (13th Ave S, 12th Ave S)	2388223	903.86 (41.12*)	34,875	893.54 (30.8*)	11,718	-10.32	-23,157
US Diversion**	2531315	914.65	21,458	922.88	11,024	8.23	-10,434
Hickson Gage**	2563754	917.52	21,730	922.90	18,655	5.38	-3,075
Abercrombie**	2764835	935.62	23,000	935.73	23,000	0.11	0
North Dakota Diversion (LPP) - 2% Chance Event (No Protection)							
Location	Station	Existing No Protection		ND Diversion (LPP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	800.72	100,869	800.80	102,165	0.08	1,296
Minimum Impact Location	1410241	811.12	97,700	811.15	98,889	0.03	1,189
Oslo Gage	1416287	812.53	97,643	812.57	98,857	0.04	1,215
Grand Forks Gage	1558518	831.13	91,118	831.31	92,619	0.18	1,501
Maximum Impact Location	1602184	836.27	69,861	836.65	70,584	0.38	723
Thompson Gage	1667877	844.83	69,367	845.07	70,104	0.24	737
Halstad Gage	1981580	867.99	59,416	867.99	59,542	0.00	126
Fargo Gage (13th Ave S, 12th Ave S)	2388223	902.6 (39.86*)	29,167	892.72 (29.98*)	10,603	-9.88	-18,565
US Diversion**	2531315	913.76	18,435	920.86	10,477	7.10	-7,959
Hickson Gage**	2563754	916.34	18,898	920.92	18,428	4.58	-470
Abercrombie**	2764835	934.48	20,726	934.62	20,726	0.14	0
North Dakota Diversion (LPP) - 10% Chance Event (No Protection)							
Location	Station	Existing No Protection		ND Diversion (LPP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	798.53	62,917	798.54	63,042	0.01	125
Minimum Impact Location	1327581	803.44	57,657	803.45	58,094	0.01	437
Oslo Gage	1416287	810.51	59,092	810.55	59,629	0.04	537
Grand Forks Gage	1558518	825.98	56,662	826.09	57,169	0.11	507
Maximum Impact Location	1561283	826.49	43,551	826.61	43,504	0.12	-47
Thompson Gage	1667877	837.58	42,815	837.62	42,843	0.04	28
Halstad Gage	1981580	864.55	34,653	864.43	34,160	-0.12	-493
Fargo Gage (13th Ave S, 12th Ave S)	2388223	897.33 (34.59*)	17,024	891.86 (29.12*)	10,156	-5.47	-6,868
US Diversion**	2531315	908.06	10,333	916.29	8,861	8.23	-1,472
Hickson Gage**	2563754	910.21	10,428	916.80	10,077	6.59	-351
Abercrombie**	2764835	929.05	11,278	929.16	11,278	0.11	0

* Flood stage at USGS Gaging Station 05054000, Fargo, ND

** Discharge does not include flow conveyed in the floodplain outside the main conveyance channel of the Red River

TABLE 3: Summary HEC-RAS Unsteady Flow Model Results for Historic Floods - Federally Comparable Plan

Minnesota Diversion (FCP) - 1997 Event (No Protection)							
Location	Station	Existing No Protection		MN Diversion (FCP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	801.95	123,404	802.05	125,375	0.10	1,971
Oslo Gage	1416287	813.29	124,661	813.34	126,501	0.05	1,840
Minimum Impact Location	1425253	814.37	107,206	814.40	108,227	0.03	1,021
Grand Forks Gage	1558518	834.04	119,103	834.21	120,893	0.17	1,790
Thompson Gage	1667877	847.29	78,351	847.66	81,143	0.37	2,792
Maximum Impact Location	1813905	859.97	71,913	860.6	74,743	0.63	2,830
Halstad Gage	1981580	868.65	64,821	868.92	68,476	0.27	3,655
Fargo Gage (13th Ave S, 12th Ave S)	2388223	902.42 (39.68*)	27,574	894.1 (31.36*)	9,978	-8.32	-17,596
US Diversion**	2470898	908.85	23,779	908.94	25,235	0.09	1456
Hickson Gage**	2563754	913.85	13,729	914.00	13,738	0.15	10
Abercrombie**	2764835	931.08	13,995	931.08	13,995	0.00	0

Minnesota Diversion (FCP) - 2006 Event (No Protection)							
Location	Station	Existing No Protection		MN Diversion (FCP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	799.44	78,252	799.47	78,770	0.03	518
Oslo Gage	1416287	811.58	74,550	811.60	74,929	0.02	379
Minimum Impact Location	1448026	814.15	67,113	814.16	67,444	0.01	331
Grand Forks Gage	1558518	828.63	72,782	828.69	73,160	0.06	378
Thompson Gage	1667877	840.63	52,499	840.84	53,450	0.21	951
Halstad Gage	1981580	866.64	43,060	866.86	44,955	0.22	1,895
Maximum Impact Location	2058853	871.99	36,500	872.36	38,554	0.37	2,054
Fargo Gage (13th Ave S, 12th Ave S)	2388223	899.57 (36.83*)	21,028	893.15 (30.41*)	10,078	-6.42	-10,950
US Diversion**	2470898	906.81	20,782	906.53	20,782	-0.28	0.00
Hickson Gage**	2563754	913.11	14,313	913.15	14,352	0.04	39
Abercrombie**	2764835	931.58	15,027	931.58	15,027	0.00	0

Minnesota Diversion (FCP) - 2009 Event (No Protection)							
Location	Station	Existing No Protection		MN Diversion (FCP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	799.85	85,308	799.98	87,702	0.13	2,393
Minimum Impact Location	1410241	810.81	83,759	810.89	87,295	0.08	3,536
Oslo Gage	1416287	812.02	85,672	812.16	87,316	0.14	1,645
Grand Forks Gage	1558518	829.33	77,165	829.83	80,831	0.50	3,666
Thompson Gage	1667877	843.05	61,510	843.97	65,379	0.92	3,869
Maximum Impact Location	1789494	853.76	58,180	854.88	62,266	1.12	4,086
Halstad Gage	1981580	867.6	55,176	868.02	60,798	0.42	5,622
Fargo Gage (13th Ave S, 12th Ave S)	2388223	902.66 (39.92*)	29,234	894.03 (31.29*)	11,964	-8.63	-17,270
US Diversion**	2470898	909.61	28,395	909.47	27,912	-0.14	-483
Hickson Gage**	2563754	917.76	24,393	917.75	24,407	-0.01	14
Abercrombie**	2764835	937.51	28,176	937.51	28,176	0.00	0

Minnesota Diversion (FCP) - 2010 Event (No Protection)							
Location	Station	Existing No Protection		MN Diversion (FCP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	798.71	65,928	798.76	66,687	0.05	759
Oslo Gage	1416287	811.09	67,101	811.11	67,463	0.02	363
Minimum Impact Location	1467237	815.28	66,433	815.30	66,870	0.02	437
Grand Forks Gage	1558518	827.23	63,406	827.29	63,783	0.06	377
Thompson Gage	1667877	840.28	52,023	840.55	53,139	0.27	1,116
Maximum Impact Location	1829650	853.73	49,914	854.1	51,122	0.37	1,208
Halstad Gage	1981580	866.55	42,389	866.76	43,888	0.21	1,499
Fargo Gage (13th Ave S, 12th Ave S)	2388223	899.77 (37.03*)	21,481	893.37 (30.63*)	10,231	-6.40	-11,250
US Diversion**	2470898	906.89	20,427	906.8	21,469	-0.09	1043
Hickson Gage**	2563754	912.23	12,677	912.42	12,697	0.19	20
Abercrombie**	2764835	930.57	13,236	930.57	13,236	0.00	0

* Flood stage at USGS Gaging Station 05054000, Fargo, ND

**Discharge does not include flow conveyed in the floodplain outside the main conveyance channel of the Red River

TABLE 4: Summary HEC-RAS Unsteady Flow Model Results for Design Floods - Federally Comparable Plan

Minnesota Diversion (FCP) - 0.2% Chance Event (No Protection)							
Location	Station	Existing No Protection		MN Diversion (FCP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	804.12	168,364	804.27	170,409	0.15	2,045
Oslo Gage	1416287	813.88	152,851	813.95	157,374	0.07	4,523
Minimum Impact Location	1416400	814.23	152,852	814.29	157,375	0.06	4,522
Grand Forks Gage	1558518	836.36	146,225	836.72	150,748	0.36	4,523
Maximum Impact Location	1580152	839.75	102,174	840.20	104,725	0.45	2,551
Thompson Gage	1667877	850.69	112,422	850.93	115,330	0.24	2,908
Halstad Gage	1981580	871.54	101,754	871.72	104,334	0.18	2,580
Fargo Gage (13th Ave S, 12th Ave S)	2388223	905.8 (43.06*)	61,717	902.83 (40.09*)	30,044	-2.97	-31,673
US Diversion**	2470898	910.99	32,153	910.81	34,471	-0.18	2,319
Hickson Gage**	2563754	919.69	35,636	919.67	35,565	-0.02	-71
Abercrombie**	2764835	940.90	44,308	940.90	44,308	0.00	0

Minnesota Diversion (FCP) - 1% Chance Event (No Protection)							
Location	Station	Existing No Protection		MN Diversion (FCP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	801.73	119,255	801.92	122,945	0.19	3,690
Minimum Impact Location	1408098	811.34	113,281	811.39	116,227	0.05	2,946
Oslo Gage	1416287	813.01	113,556	813.09	116,500	0.08	2,944
Grand Forks Gage	1558518	832.97	107,980	833.35	112,047	0.38	4,067
Thompson Gage	1667877	847.35	82,926	848.11	88,519	0.76	5,593
Maximum Impact Location	1813905	860.78	75,611	862.01	81,907	1.23	6,296
Halstad Gage	1981580	869.09	71,581	869.68	80,624	0.59	9,043
Fargo Gage (13th Ave S, 12th Ave S)	2388223	903.86 (41.12*)	34,875	894.91 (32.17*)	11,756	-8.95	-23,119
US Diversion**	2470898	910.13	29,330	910.71	22,794	0.58	-6,536
Hickson Gage**	2563754	917.52	21,730	917.51	21,734	-0.01	3
Abercrombie**	2764835	935.62	23,000	935.62	23,000	0.00	0

Minnesota Diversion (FCP) - 2% Chance Event (No Protection)							
Location	Station	Existing No Protection		MN Diversion (FCP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	800.72	100,869	800.83	102,845	0.11	1,976
Oslo Gage	1416287	812.53	97,643	812.56	98,491	0.03	848
Minimum Impact Location	1448026	814.89	84,147	814.91	85,013	0.02	867
Grand Forks Gage	1558518	831.13	91,118	831.26	92,141	0.13	1,023
Thompson Gage	1667877	844.83	69,367	845.61	73,330	0.78	3,963
Maximum Impact Location	1829650	858.51	63,541	859.52	67,966	1.01	4,425
Halstad Gage	1981580	867.99	59,416	868.47	65,150	0.48	5,735
Fargo Gage (13th Ave S, 12th Ave S)	2388223	902.6 (39.86*)	29,167	894.02 (31.28*)	10,878	-8.58	-18,289
US Diversion**	2470898	909.54	27,658	909.4	27,987	-0.14	329
Hickson Gage**	2563754	916.34	18,898	916.37	18,925	0.03	27
Abercrombie**	2764835	934.48	20,726	934.49	20,726	0.01	0

Minnesota Diversion (FCP) - 10% Chance Event (No Protection)							
Location	Station	Existing No Protection		MN Diversion (FCP)		Difference (ft) Project vs. Existing No Protection	
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)
Drayton Gage	1062362	798.53	62,917	798.57	63,651	0.04	734
Minimum Impact Location	1410241	809.75	58,880	809.78	59,596	0.03	717
Oslo Gage	1416287	810.51	59,092	810.56	59,699	0.05	607
Grand Forks Gage	1558518	825.98	56,662	826.10	57,258	0.12	596
Thompson Gage	1667877	837.58	42,815	837.82	43,590	0.24	775
Halstad Gage	1981580	864.55	34,653	864.88	35,715	0.33	1,063
Maximum Impact Location	2236491	883.37	29,991	883.82	32,040	0.45	2,048
Fargo Gage (13th Ave S, 12th Ave S)	2388223	897.33 (34.59*)	17,024	892.66 (29.92*)	9,933	-4.67	-7,091
US Diversion**	2470898	904.54	16,759	904.71	17,329	0.17	570
Hickson Gage**	2563754	910.21	10,428	910.27	10,459	0.06	31
Abercrombie**	2764835	929.05	11,278	929.05	11,278	0.00	0

* Flood stage at USGS Gaging Station 05054000, Fargo, ND

** Discharge does not include flow conveyed in the floodplain outside the main conveyance channel of the Red River

Fargo-Moorhead Metro Flood Risk Management Project

Table 5
LPP North Dakota Diversion - MII Cost Estimate Summary
Phase 4 - MII Estimate 2-28-2011

North Dakota Diversion				
Description	Contract Cost	(1) Contingency	Project Cost	Percent of Total
RELOCATIONS				
Roadway Bridges, Road Raises & Local Road Construction	103,611,762	14,740,166	118,351,928	11.74%
Railroad Bridges	46,497,415	13,614,538	60,111,954	5.96%
CHANNELS AND CANALS				
Diversion Channel	318,633,134	63,726,627	382,359,760	37.91%
Control Structure on Red River	47,355,147	9,471,029	56,826,177	5.63%
Hydraulic Structure at Wolverton Creek	4,290,478	858,096	5,148,573	0.51%
Hydraulic Structure at Wild Rice River	29,348,084	5,869,617	35,217,701	3.49%
Hydraulic Structure - East Weir (at Connecting Channel)	219,666	43,933	263,599	0.03%
Hydraulic Structure - Inlet Weir to Diversion	9,786,068	1,957,214	11,743,281	1.16%
Hydraulic Structures at Sheyenne River	49,677,739	9,935,548	59,613,286	5.91%
Hydraulic Structure - Drain 14 - Large Drain Structure	8,236,281	1,647,256	9,883,537	0.98%
Hydraulic Structures at Maple River	45,108,856	9,021,771	54,130,627	5.37%
Hydraulic Structures at Lower Rush River	17,256,300	3,451,260	20,707,560	2.05%
Hydraulic Structures at Rush River	17,215,143	3,443,029	20,658,171	2.05%
Small Drain Structures (2)	252,369	126,185	378,554	0.04%
Large Drain Structure (1)	448,922	224,461	673,383	0.07%
Side Channel Inlets 1x72" (19)	8,343,417	4,171,708	12,515,125	1.24%
Side Channel Inlets 2x72" (7)	5,616,955	2,808,477	8,425,432	0.84%
Outlet to Red River	22,007,824	4,401,565	26,409,389	2.62%
LEVEES AND FLOODWALLS				
Tie-Back Levee - TBL East 2B (Constructed in MN)	18,573,020	3,714,604	22,287,624	2.21%
Tie-Back Levee - TBL Cass 17 (Constructed in ND)	6,320,611	1,264,122	7,584,733	0.75%
Levee - Connecting Channel - Reach 2018 (ND-23, 26)	1,683,581	336,716	2,020,297	0.20%
Levee - Connecting Channel - Reach 2019 (ND-25)	6,971,436	1,394,287	8,365,723	0.83%
Storage Area 1 Embankment and Inlet	57,965,277	14,481,249	72,446,526	7.18%
Storage Area 1 Closure/Drainage Structure (North)	5,169,828	1,033,966	6,203,794	0.62%
Storage Area 1 Closure/Drainage Structure (East)	5,169,828	1,033,966	6,203,794	0.62%
Subtotal	**$835,759,138**	**$172,771,389**	**$1,008,530,528**	**100.0%**

(1) Allowance for costs that will be in the Project Cost and are not included in Contract Cost. Does not account for changed conditions either in final design or during construction.

Fargo-Moorhead Metro Flood Risk Management Project

Table 6

FCP Minnesota Diversion - MII Cost Estimate Summary

Phase 4 - MII Estimate Revised 2-28-2011

Minnesota Diversion

Description	Contract Cost	(1) Contingency	Project Cost	Percent of total
RELOCATIONS				
Roadway bridges	79,730,554	9,309,137	89,039,691	11.3%
Railroad bridges	132,712,322	39,662,974	172,375,295	21.8%
CHANNELS AND CANALS				
Diversion channel	353,339,582	70,667,916	424,007,499	53.6%
Control structure on Red River	59,545,729	11,909,146	71,454,875	9.0%
Small drain structure (3)	752,396	376,198	1,128,593	0.1%
Side channel inlet 1x72" (7)	3,128,818	1,564,409	4,693,227	0.6%
Side channel inlet 2x72" (11)	8,986,446	4,493,223	13,479,669	1.7%
Channel Drop Structure	2,123,007	424,601	2,547,609	0.3%
Outlet to Red River	1,595,053	319,011	1,914,064	0.2%
LEVEES AND FLOODWALLS				
Levees and floodwalls	8,246,709	1,954,203	10,200,912	1.3%
Subtotal	**$650,160,615**	**$140,680,818**	**$790,841,433**	**100.0%**

(1) Allowance for costs that will be in the Project Cost and are not included in Contract Cost. Does not account for changed conditions either in final design or during construction.

Fargo-Moorhead Metro Flood Risk Management Project

Table 7
LPP North Dakota Diversion - MII Cost Estimate Summary
Phase 4 - MII Estimate Revised 4-18-2011 following USACE Agency Technical Review (ATR)

North Dakota Diversion				
Description	Contract Cost	(1) Contingency	Project Cost	Percent of Total
RELOCATIONS				
Roadway Bridges, Road Raises & Local Road Construction	103,611,762	0	103,611,762	11.91%
RAILROAD BRIDGES				
Railroad Bridges	46,497,415	0	46,497,415	5.35%
CHANNELS AND CANALS				
Diversion Channel	338,217,173	0	338,217,173	38.88%
Control Structure on Red River	48,276,228	0	48,276,228	5.55%
Hydraulic Structure at Wolverton Creek	4,366,235	0	4,366,235	0.50%
Hydraulic Structure at Wild Rice River	29,630,288	0	29,630,288	3.41%
Hydraulic Structure - East Weir (at Connecting Channel)	215,712	0	215,712	0.02%
Hydraulic Structure - Inlet Weir to Diversion	9,942,054	0	9,942,054	1.14%
Hydraulic Structures at Sheyenne River	50,805,769	0	50,805,769	5.84%
Hydraulic Structure - Drain 14 - Large Drain Structure	8,378,185	0	8,378,185	0.96%
Hydraulic Structures at Maple River	45,799,454	0	45,799,454	5.26%
Hydraulic Structures at Lower Rush River	17,743,527	0	17,743,527	2.04%
Hydraulic Structures at Rush River	17,709,812	0	17,709,812	2.04%
Small Drain Structures (2)	254,374	0	254,374	0.03%
Large Drain Structure (1)	447,425	0	447,425	0.05%
Side Channel Inlets 1x72" (19)	8,454,002	0	8,454,002	0.97%
Side Channel Inlets 2x72" (7)	5,662,176	0	5,662,176	0.65%
Outlet to Red River	22,704,305	0	22,704,305	2.61%
LEVEES AND FLOODWALLS				
Tie-Back Levee - TBL East 2B (Constructed in MN)	19,829,863	0	19,829,863	2.28%
Tie-Back Levee - TBL Cass 17 (Constructed in ND)	6,801,067	0	6,801,067	0.78%
Levee - Connecting Channel - Reach 2018 (ND-23, 26)	1,830,998	0	1,830,998	0.21%
Levee - Connecting Channel - Reach 2019 (ND-25)	7,570,035	0	7,570,035	0.87%
Storage Area 1 Embankment and Inlet	62,505,446	0	62,505,446	7.19%
Storage Area 1 Closure/Drainage Structure (North)	5,332,286	0	5,332,286	0.61%
Storage Area 1 Closure/Drainage Structure (East)	5,332,286	0	5,332,286	0.61%
Road Raise for LPP SA1 Levees ND	1,987,535	0	1,987,535	0.23%
Subtotal	**$869,905,414**	**$0**	**$869,905,414**	**100.0%**

(1) Contingency must be added to complete this estimate. Contingency to be determined by USACE with Cost Schedule Risk Analysis (CSRA). Allowance for costs that will be in the Project Cost and are not included in Contract Cost. Does not account for changed conditions either in final design or during construction. A/E recommended contingencies were presented in the 2-28-2011 deliverable to USACE (See Table 5).

Fargo-Moorhead Metro Flood Risk Management Project

Table 8

FCP Minnesota Diversion - MII Cost Estimate Summary

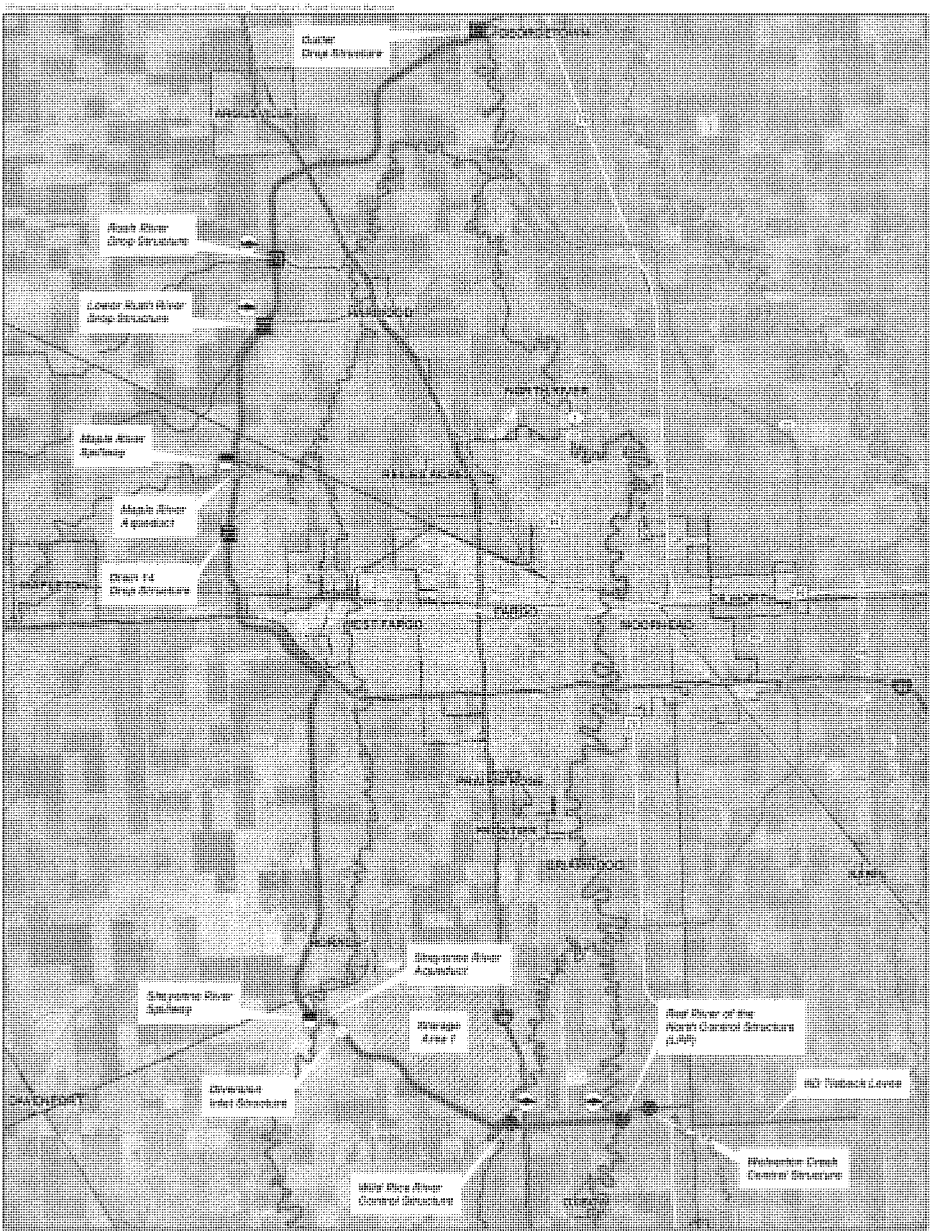
Phase 4 - MII Estimate Revised 4-18-2011 following USACE Agency Technical Review (ATR)

Minnesota Diversion

Description	Contract Cost	(1) Contingency	Project Cost	Percent of total
RELOCATIONS				
Roadway bridges	79,730,554	0	79,730,554	11.6%
RAILROAD BRIDGES				
Railroad bridges	127,294,440	0	127,294,440	18.4%
CHANNELS AND CANALS				
Diversion channel	385,841,384	0	385,841,384	55.9%
Control structure on Red River	64,323,225	0	64,323,225	9.3%
Small drain structure (3)	785,494	0	785,494	0.1%
Side channel inlet 1x72" (7)	3,180,752	0	3,180,752	0.5%
Side channel inlet 2x72" (11)	9,076,396	0	9,076,396	1.3%
Channel Drop Structure	4,312,324	0	4,312,324	0.6%
Outlet to Red River	1,617,839	0	1,617,839	0.2%
LEVEES AND FLOODWALLS				
Levees and floodwalls	14,144,391	0	14,144,391	2.0%
Subtotal	**$690,306,798**	**$0**	**$690,306,798**	**100.0%**

(1) Contingency must be added to complete this estimate. Contingency to be determined by USACE with Cost Schedule Risk Analysis (CSRA). Allowance for costs that will be in the Project Cost and are not included in Contract Cost. Does not account for changed conditions either in final design or during construction. A/E recommended contingencies were presented in the 2-28-2011 deliverable to USACE (See Table 6).

Figures



Hydraulic Structures

- Weir
- Aqueduct
- Control Structure
- Drop Structure
- Spillway
- Fish Passageway

ND Tieback Levee

North Dakota Diversion
Locally Preferred Plan (LPP)

Minnesota Diversion
Federally Comparable Plan (FCP)

Channel Reclamation Reaches

Storage Area 1

Figure 1

PROJECT
OVERVIEW

Fargo - Moorhead Area

0 0.5 1 2 3 4
Miles

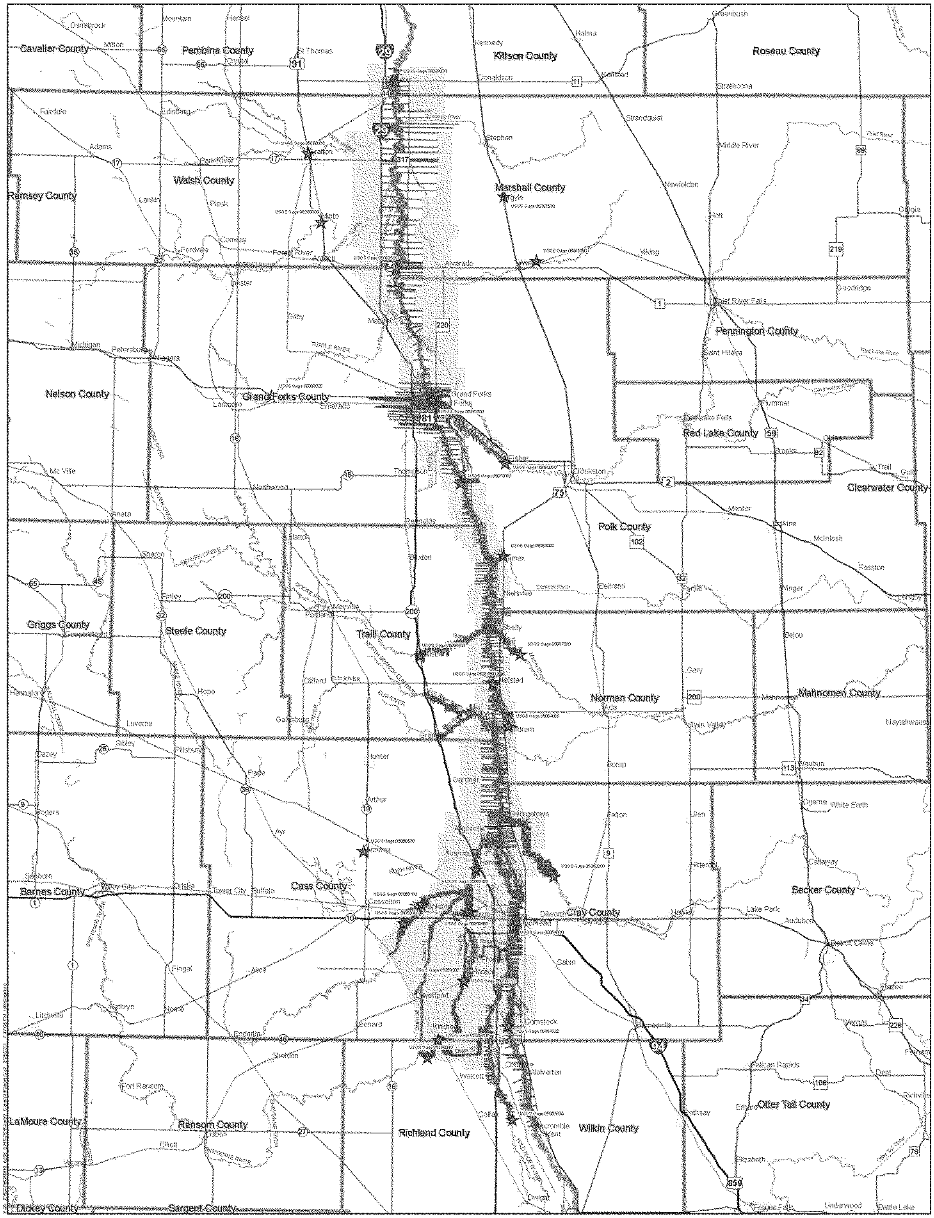


Figure 2

Unsteady HEC-RAS Modeling
Study Area Map

USGS Gages
Existing Conditions Model Cross Sections
Existing Conditions Model Reaches
Existing Conditions Model Storage Areas
Model Cross Sections
City Boundaries
Counties

0 3 6 12 18
Miles

Figure 3 Longitudinal Profile of LPP Diversion Channel

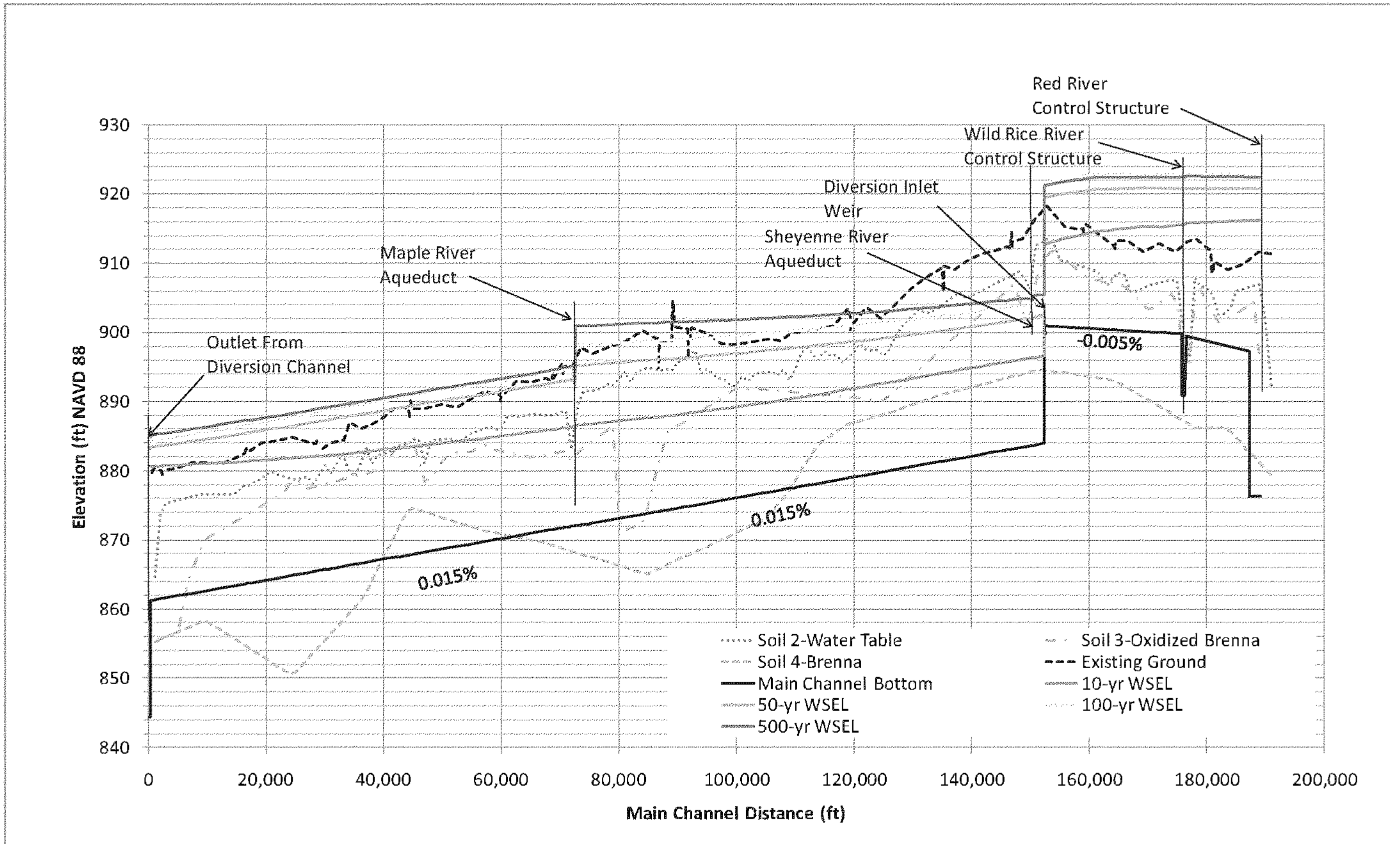
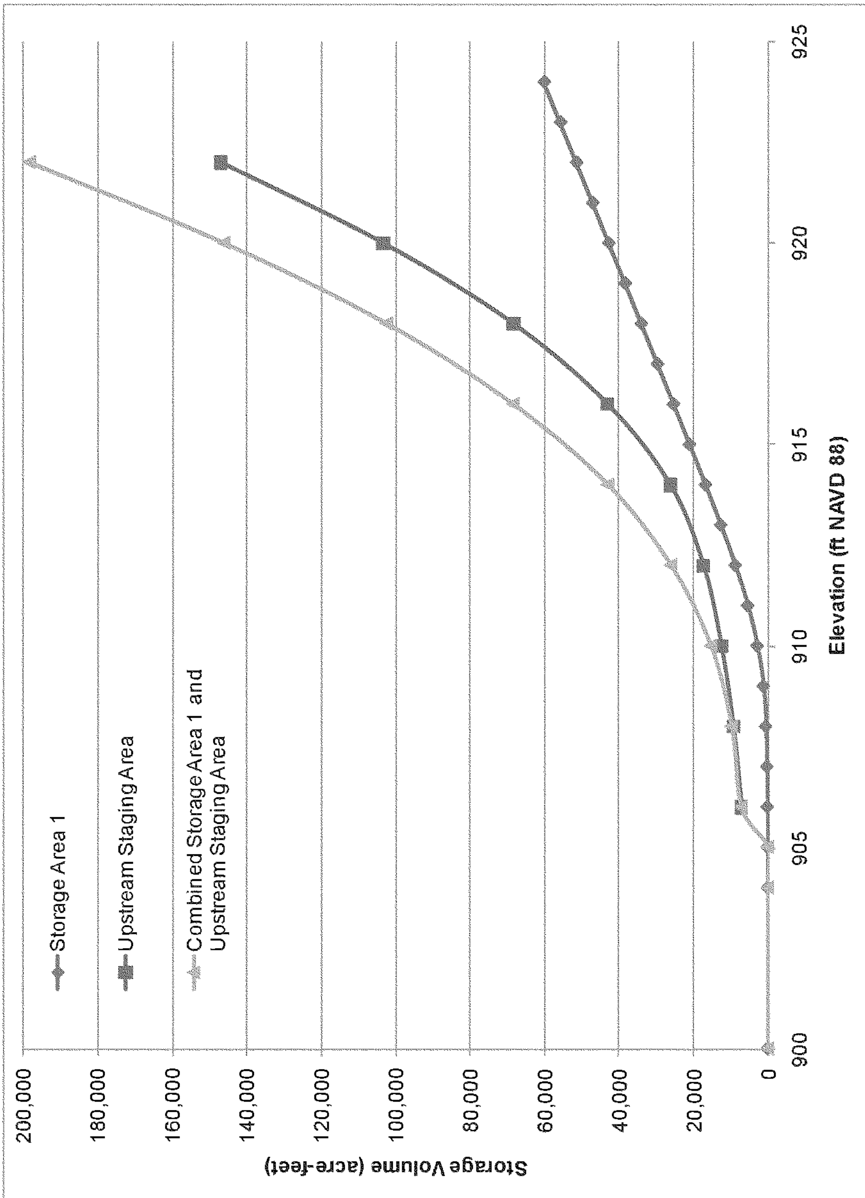
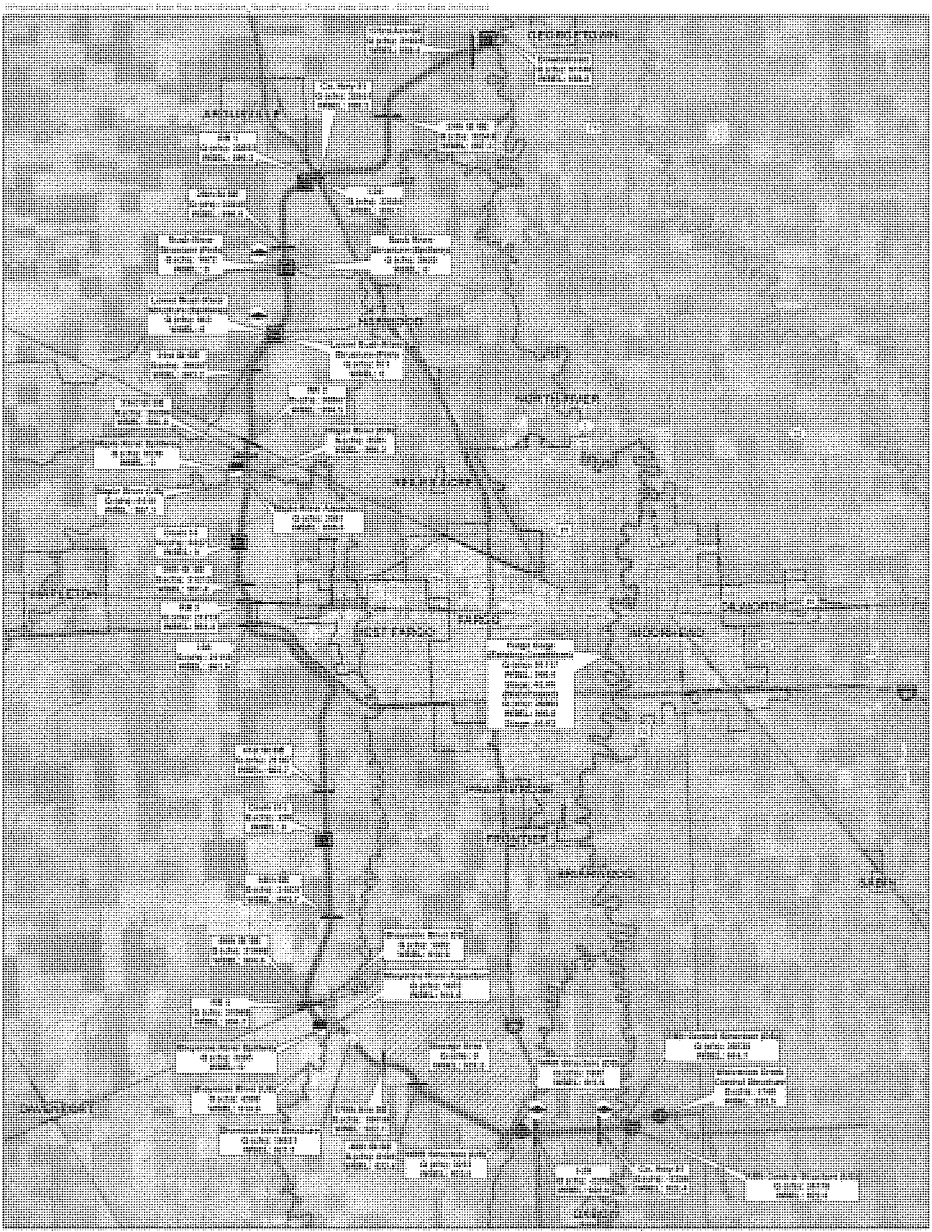


Figure 4 Storage Elevation Curves for Upstream Staging Area and Storage Area 1





Hydraulic Structures

- Weir
- Aqueduct
- Control Structure
- Drop Structure
- Spillway
- Fish Passageway

- North Dakota Diversion Locally Preferred Plan (LPP)
- ND Tieback Levee
- Channel Reclamation Reaches
- Bridge Reconstruction
- Storage Area 1

Note: Flows in rivers (US) are in main channel only. Flows in overbanks/floodplain are not reported.

Figure 5

FLOWS AND WATER SURFACE ELEVATIONS AT MAIN LPP PROJECT FEATURES FOR 0.2-PERCENT CHANCE EVENT IN RED RIVER OF THE NORTH (AND COINCIDENTAL EVENT IN ND TRIBUTARIES)
Fargo - Moorhead Area

N

0 0.5 1 2 3 4 Miles

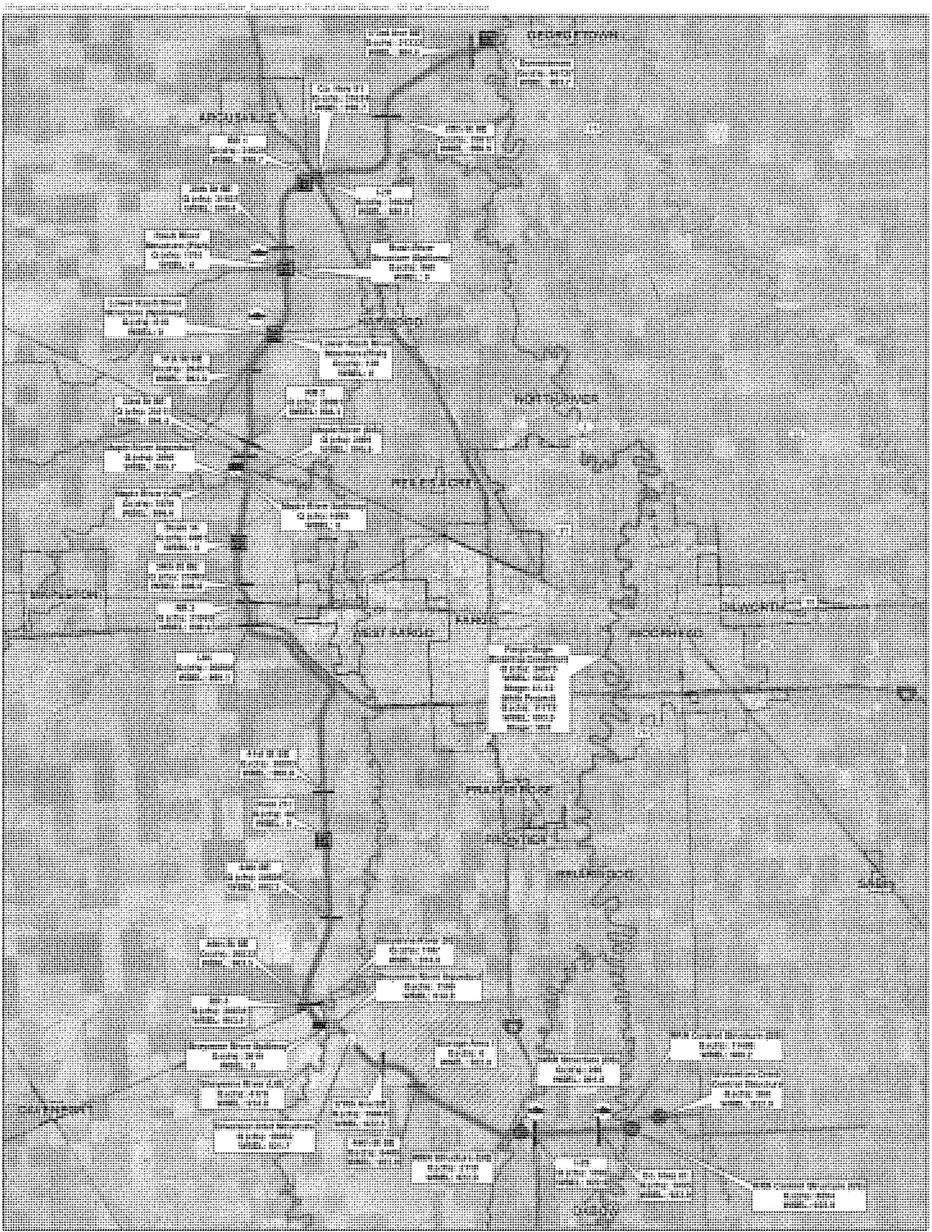
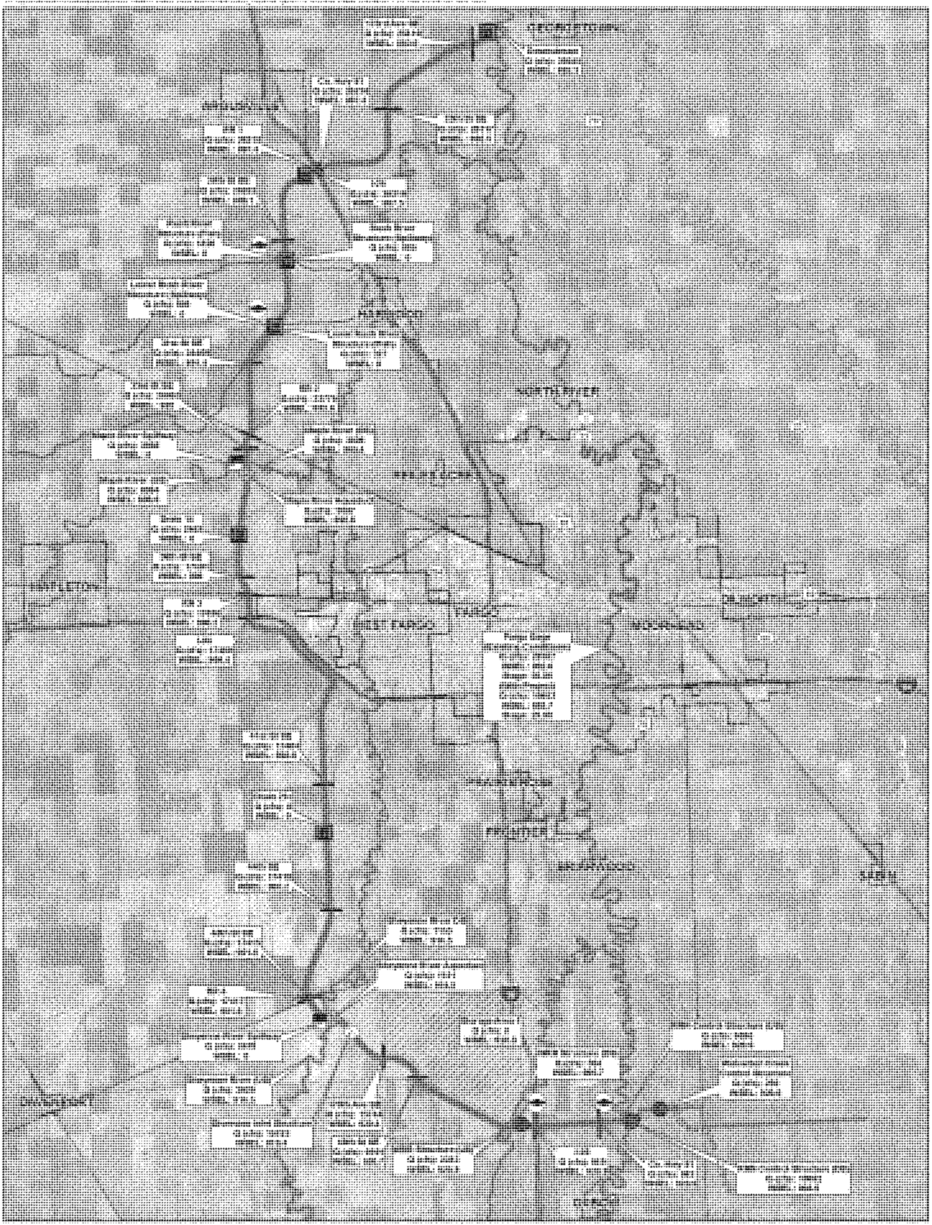


Figure 6

FLOWS AND WATER SURFACE ELEVATIONS AT MAIN LPP PROJECT FEATURES FOR 1-PERCENT CHANCE EVENT IN RED RIVER OF THE NORTH (AND COINCIDENTAL EVENT IN ND TRIBUTARIES)
Fargo - Moorhead Area



Hydraulic Structures
- Weir
- Aqueduct
- Control Structure
- Drop Structure
- Spillway
- Fish Passageway

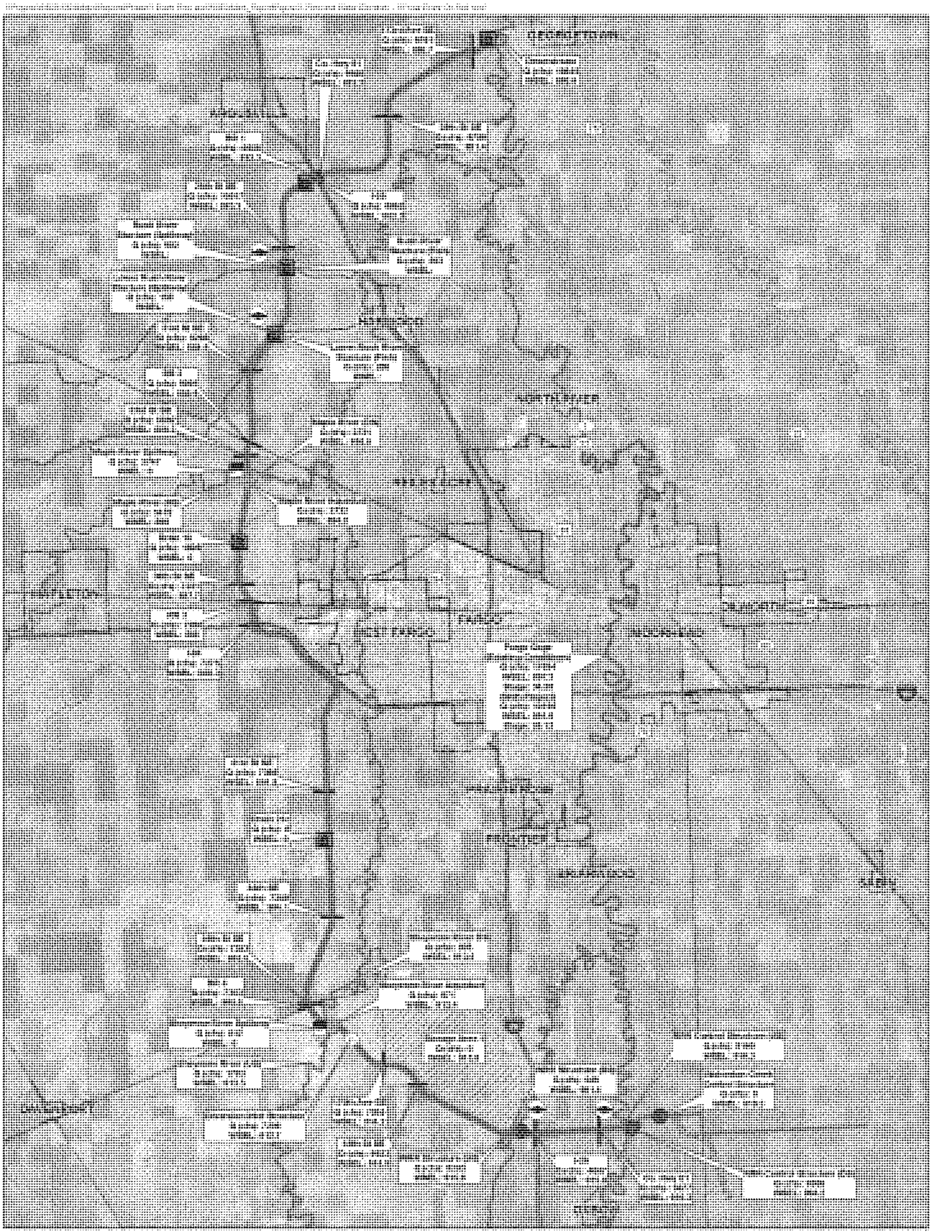
North Dakota Diversion Locally Preferred Plan (LPP)
ND Tieback Levee
Channel Reclamation Reaches
Bridge Reconstruction
Storage Area 1

Note: Flows in rivers (US) are in main channel only. Flows in overbanks/floodplain are not reported.

Figure 7

FLOWS AND WATER SURFACE ELEVATIONS AT MAIN LPP PROJECT FEATURES FOR 2-PERCENT CHANCE EVENT IN RED RIVER OF THE NORTH (AND COINCIDENTAL EVENT IN ND TRIBUTARIES)
Fargo - Moorhead Area

0 0.5 1 2 3 4 Miles



Hydraulic Structures

- Weir
- Aqueduct
- Control Structure
- Drop Structure
- Spillway
- Fish Passageway

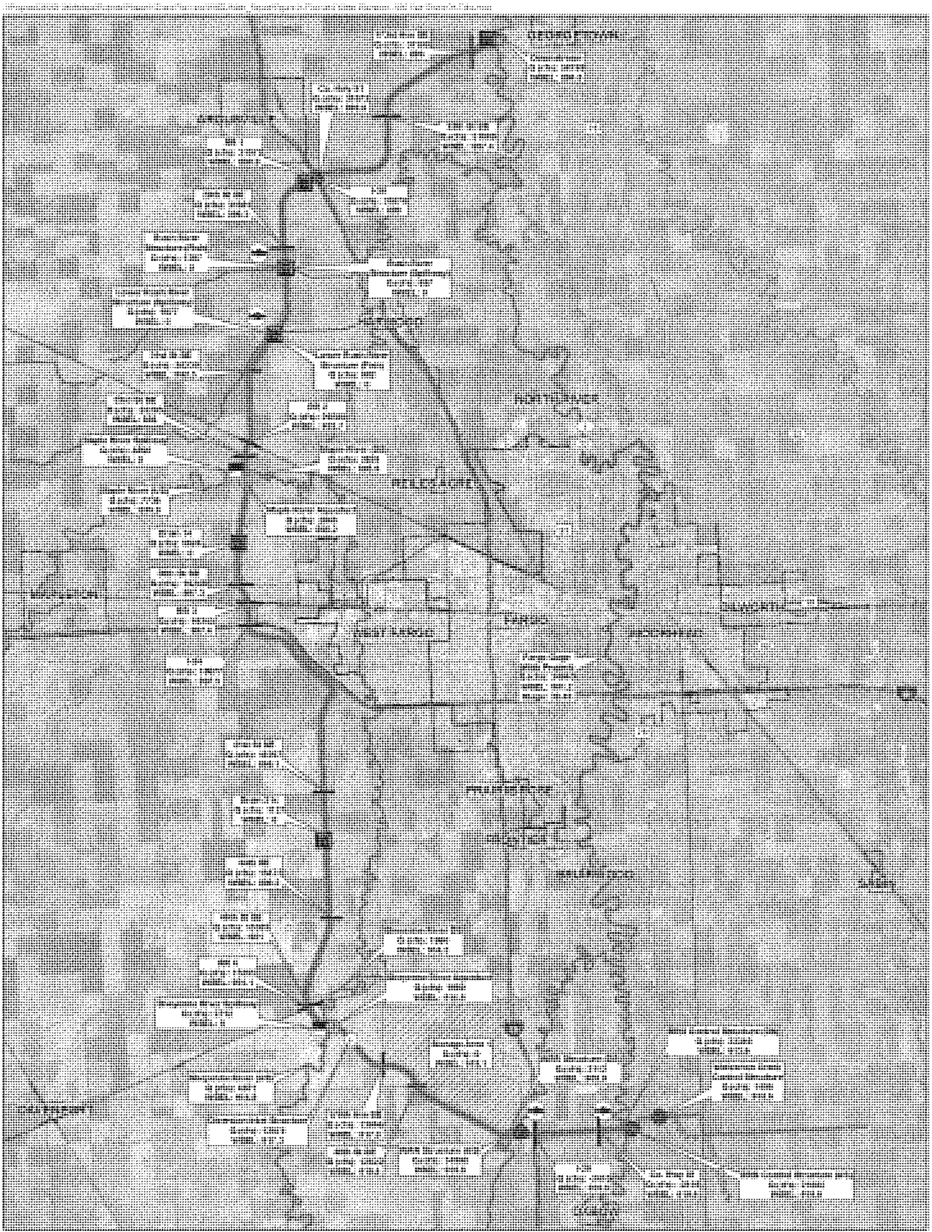
North Dakota Diversion Locally Preferred Plan (LPP)
ND Tieback Levee
Channel Reclamation Reaches
Bridge Reconstruction
Storage Area 1

Note: Flows in rivers (US) are in main channel only. Flows in overbanks/floodplain are not reported.

Figure 8

FLOWS AND WATER SURFACE ELEVATIONS AT MAIN LPP PROJECT FEATURES FOR 10-PERCENT CHANCE EVENT IN RED RIVER OF THE NORTH (AND COINCIDENTAL EVENT IN ND TRIBUTARIES)
Fargo - Moorhead Area

0 0.5 1 2 3 4 Miles



Hydraulic Structures

- Weir
- Aqueduct
- Control Structure
- Drop Structure
- Spillway
- Fish Passageway

North Dakota Diversion Locally Preferred Plan (LPP)

ND Tieback Levee

Channel Reclamation Reaches

Bridge Reconstruction

Storage Area 1

Note: Flows in rivers (US) are in main channel only. Flows in overbanks/floodplain are not reported.

Figure 9

FLOWS AND WATER SURFACE ELEVATIONS AT MAIN LPP PROJECT FEATURES FOR 0.2-PERCENT CHANCE EVENT IN ND TRIBUTARIES (AND COINCIDENTAL EVENT IN RED RIVER OF THE NORTH)
Fargo - Moorhead Area

N

0 0.5 1 2 3 4 Miles

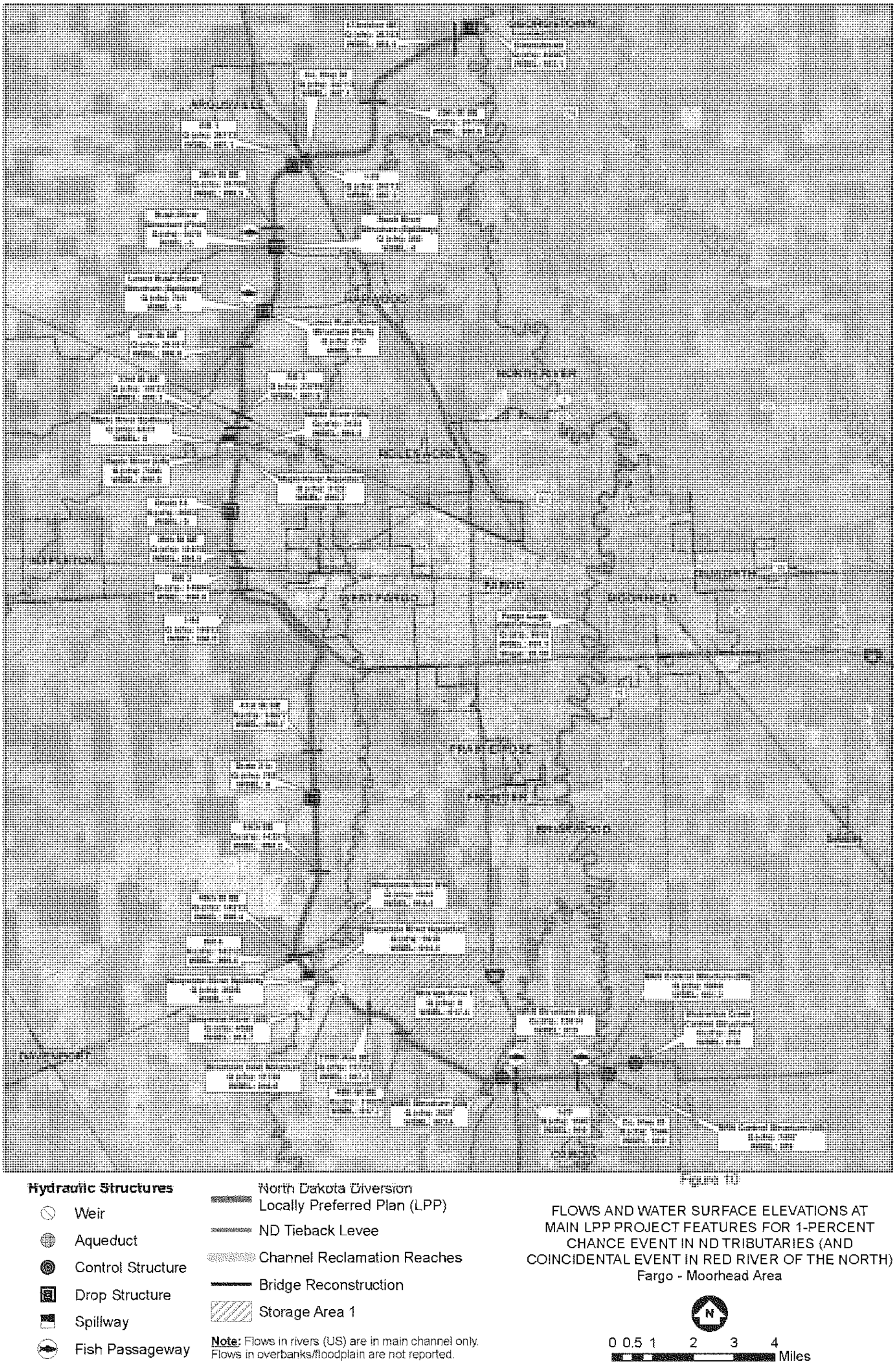


Figure 10

FLOWS AND WATER SURFACE ELEVATIONS AT MAIN LPP PROJECT FEATURES FOR 1-PERCENT CHANCE EVENT IN ND TRIBUTARIES (AND COINCIDENTAL EVENT IN RED RIVER OF THE NORTH)
Fargo - Moorhead Area

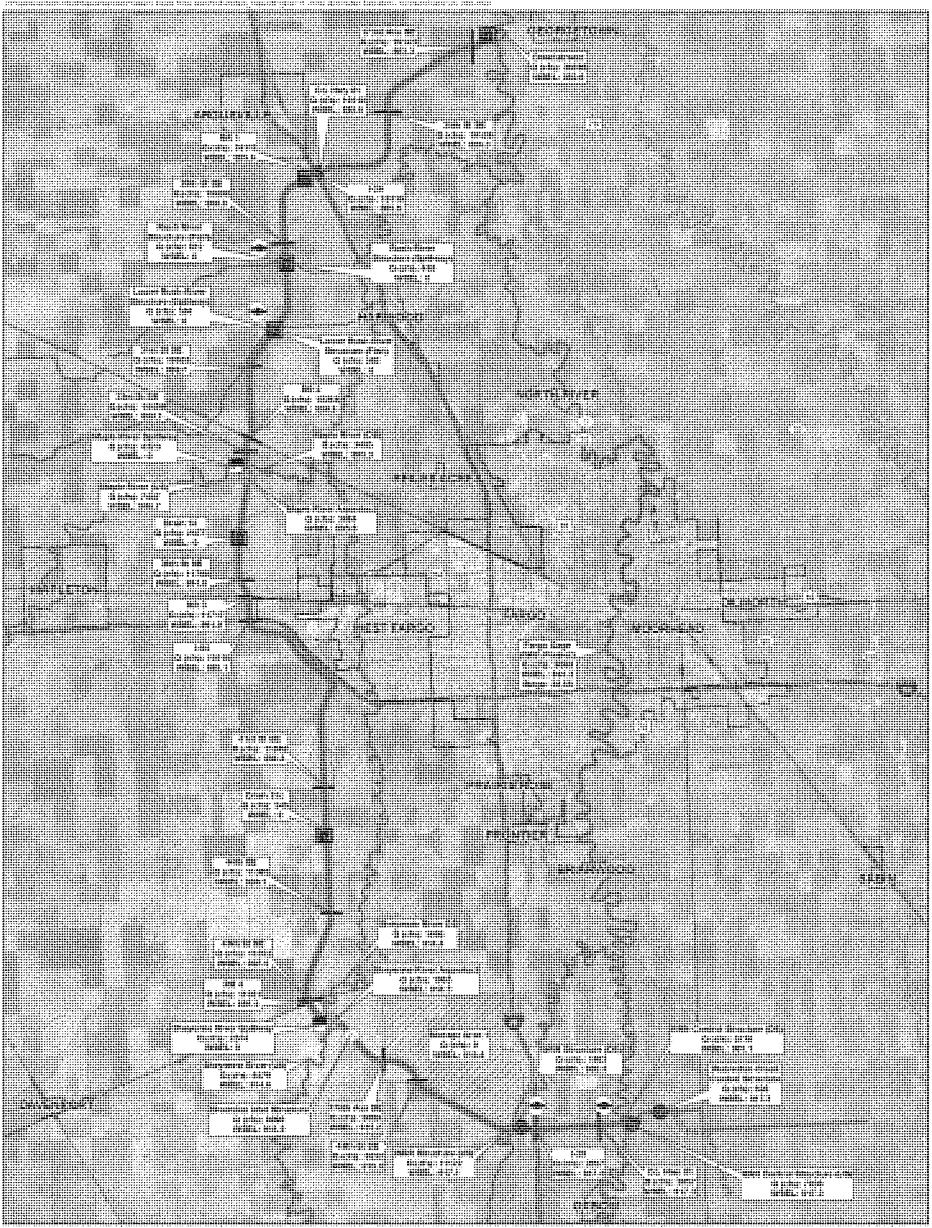
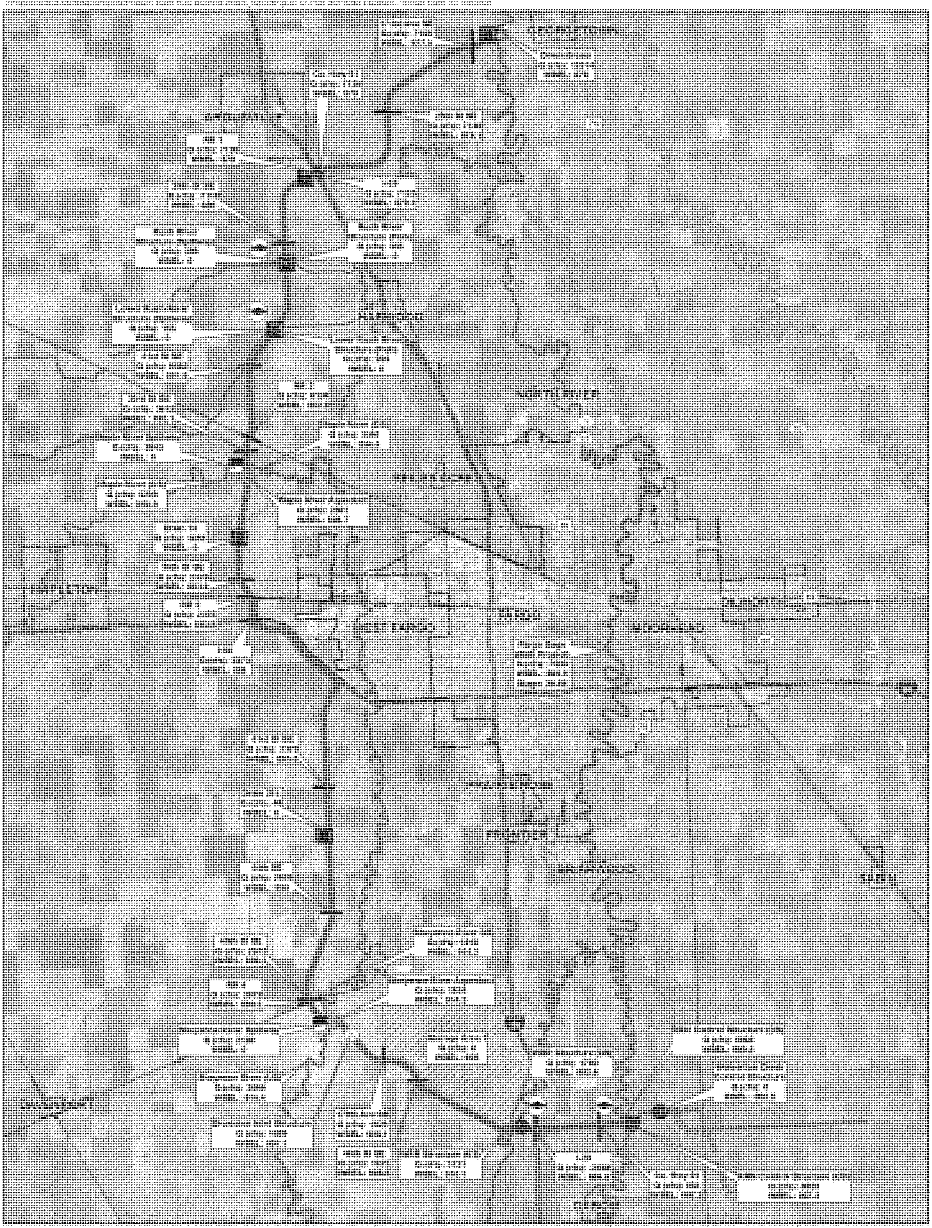


Figure 11

FLOWS AND WATER SURFACE ELEVATIONS AT MAIN LPP PROJECT FEATURES FOR 2-PERCENT CHANCE EVENT IN ND TRIBUTARIES (AND COINCIDENTAL EVENT IN RED RIVER OF THE NORTH)
Fargo - Moorhead Area



Hydraulic Structures

- Weir
- Aqueduct
- Control Structure
- Drop Structure
- Spillway
- Fish Passageway

North Dakota Diversion Locally Preferred Plan (LPP)

ND Tieback Levee

Channel Reclamation Reaches

Bridge Reconstruction

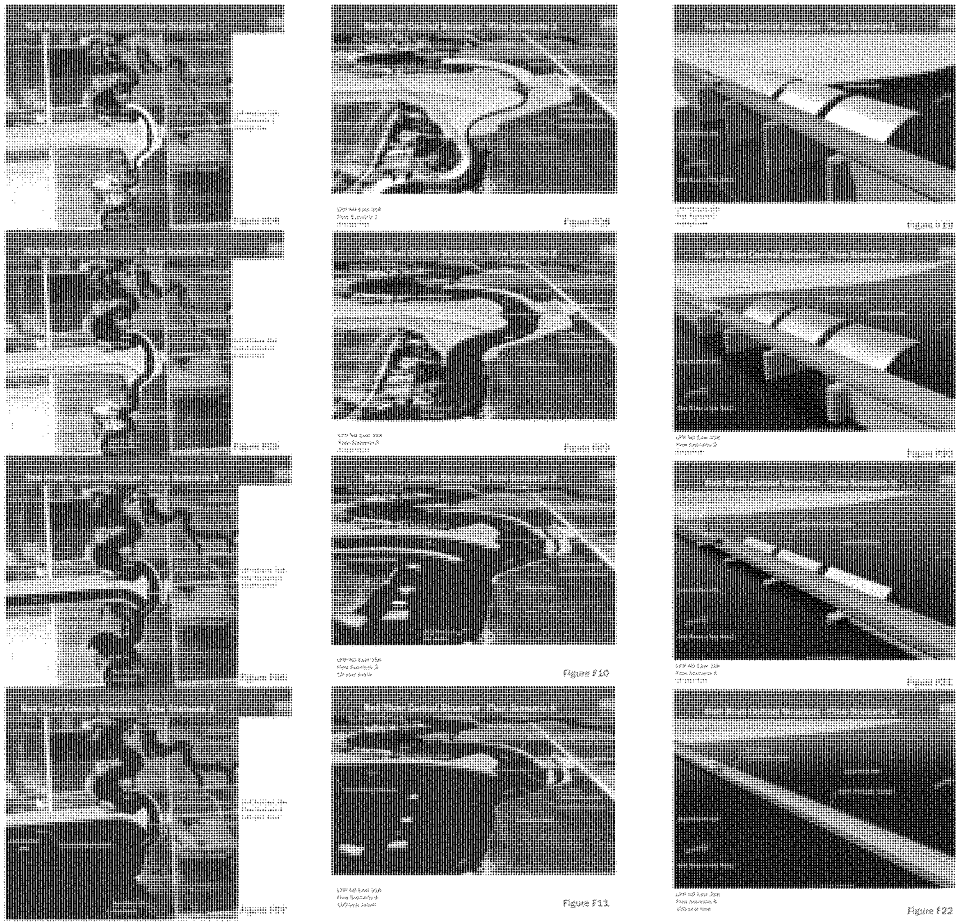
Storage Area 1

Note: Flows in rivers (US) are in main channel only. Flows in overbanks/floodplain are not reported.

Figure 12

FLOWS AND WATER SURFACE ELEVATIONS AT MAIN LPP PROJECT FEATURES FOR 10-PERCENT CHANCE EVENT IN ND TRIBUTARIES (AND COINCIDENTAL EVENT IN RED RIVER OF THE NORTH)
Fargo - Moorhead Area

0 0.5 1 2 3 4 Miles



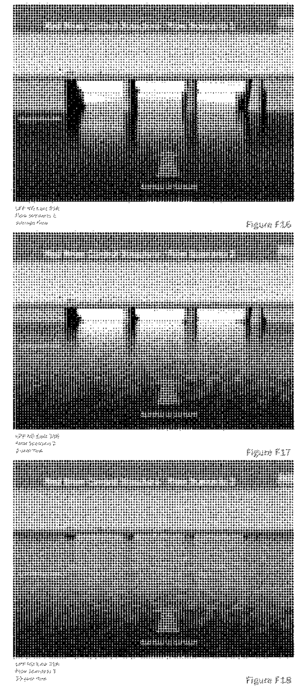


Figure 13
MOSAIC OF RENDERINGS OF
RED RIVER LPP CONTROL STRUCTURE

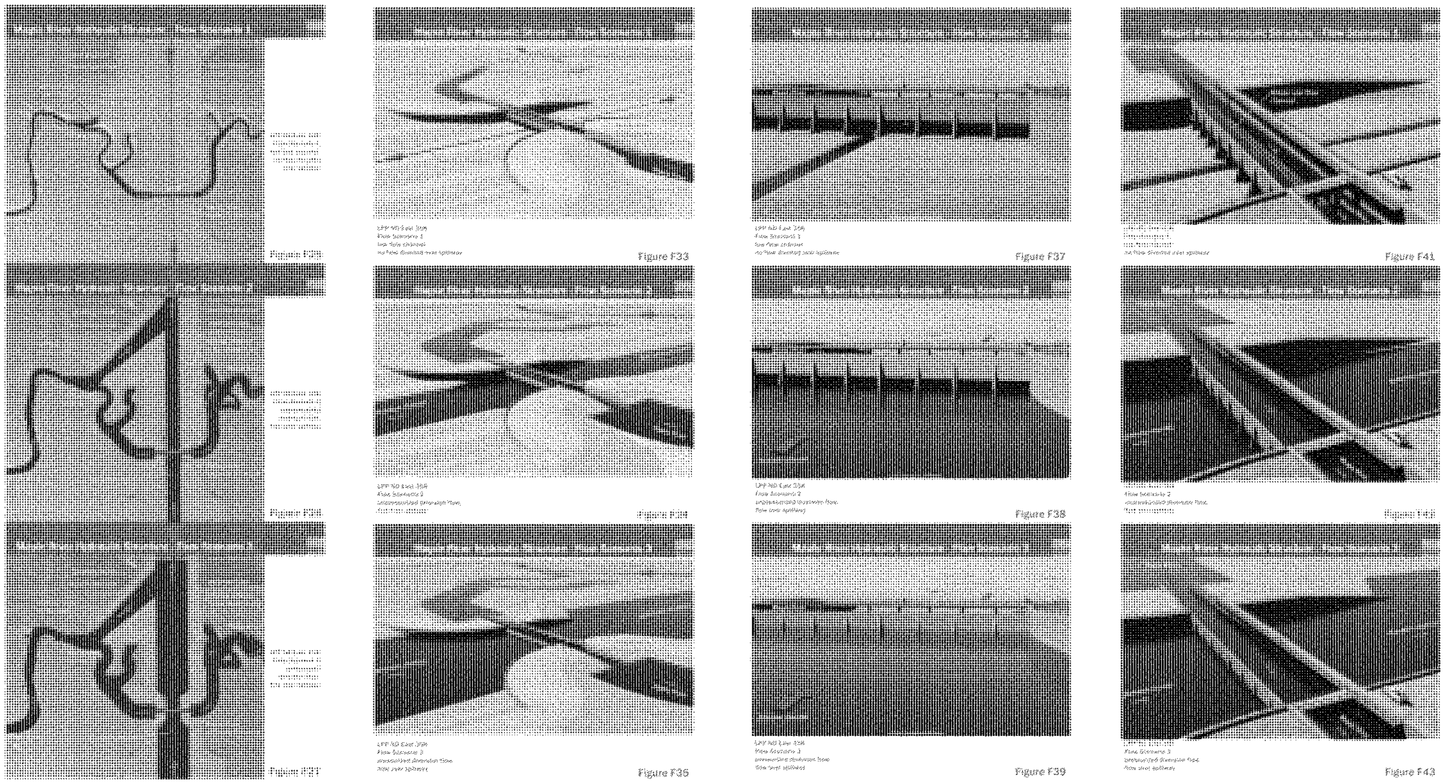
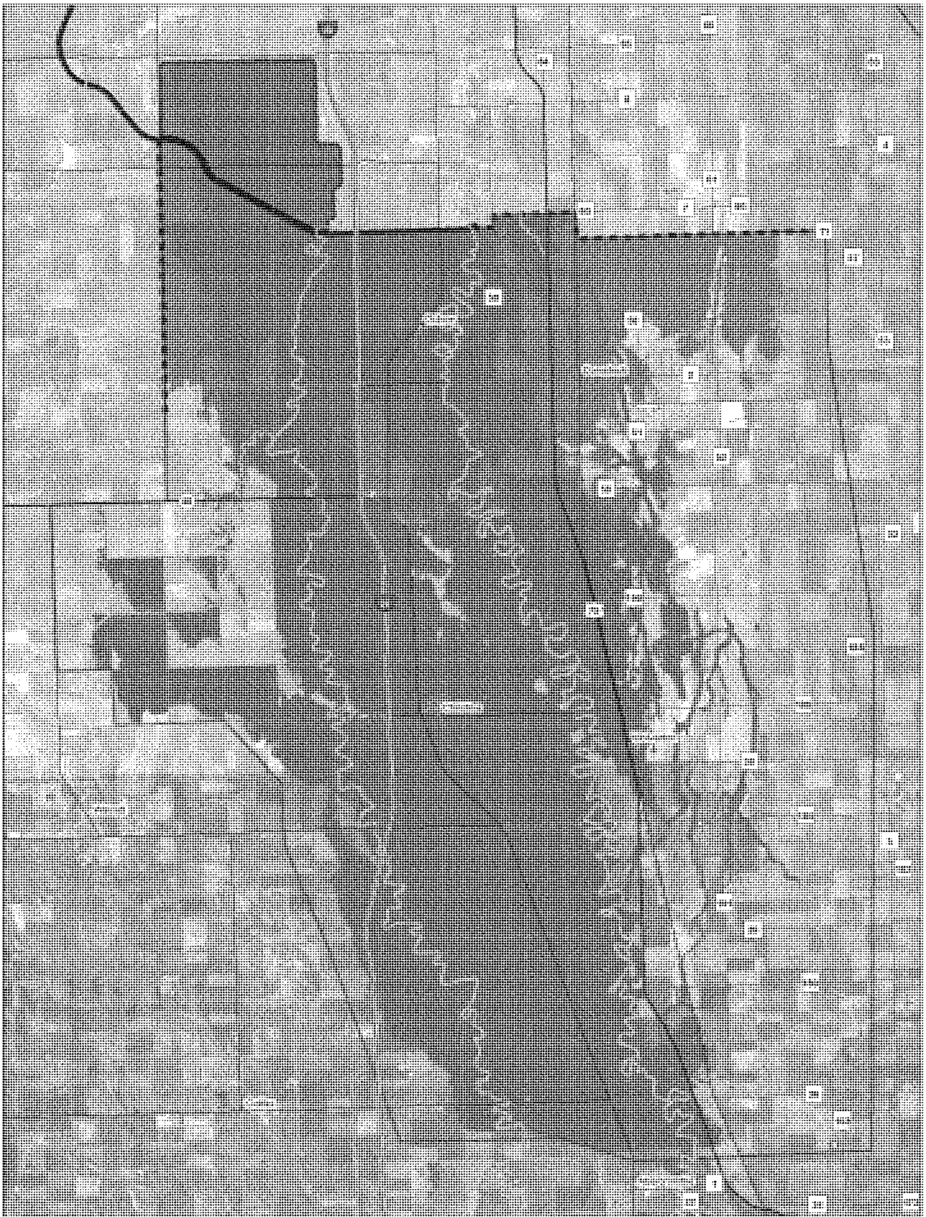


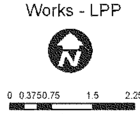
Figure 14
MOSAIC OF RENDERINGS OF
MAPLE RIVER HYDRAULIC STRUCTURES



0.2% Existing (66,566 Acres)
LPP 0.2% (78,876 Acres)
Mapping Extent
Storage Area 1
LPP Diversion
LPP Tieback
Cities

Figure 15

Inundation Map for the Model Existing Conditions and With Project for 0.2-percent Chance Event in the Red River of the North - South of Diversion Works - LPP



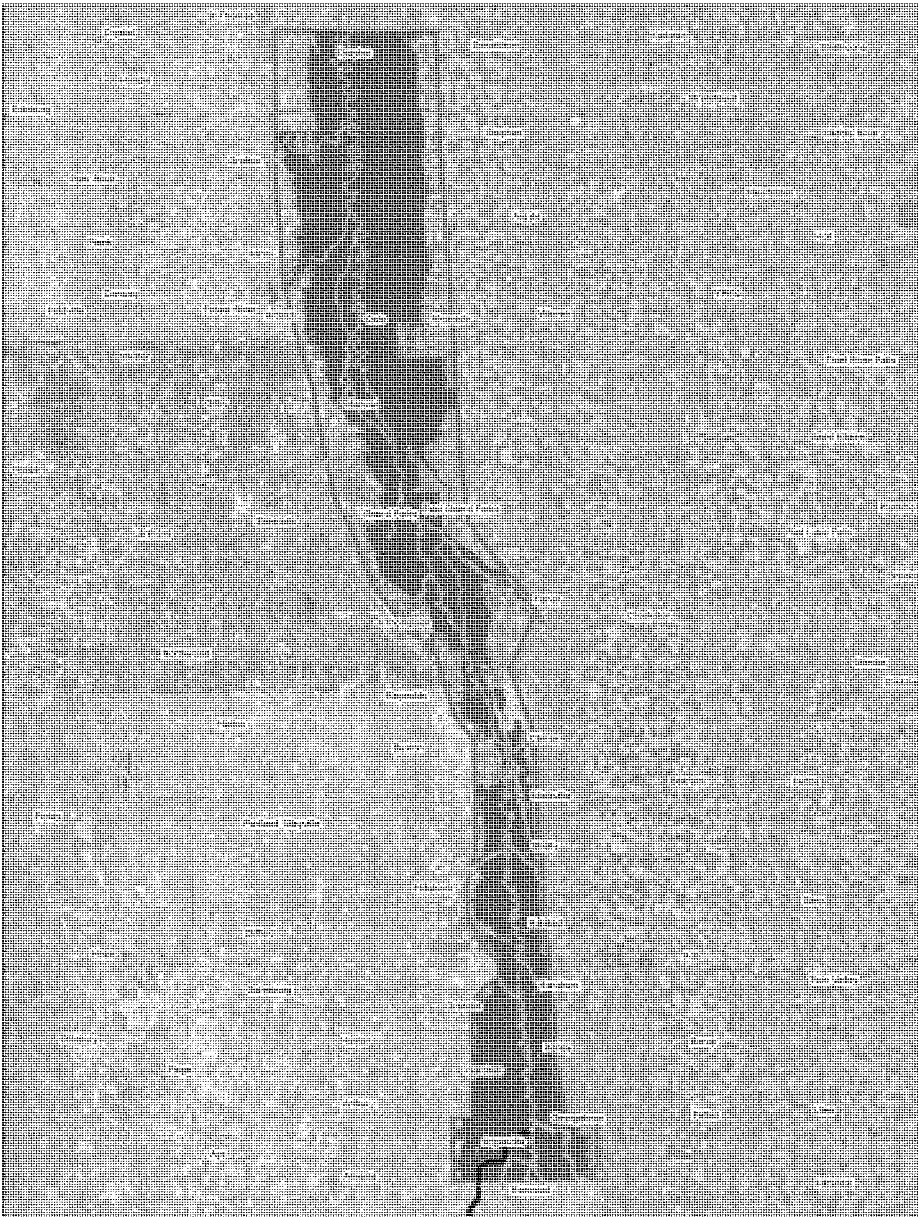
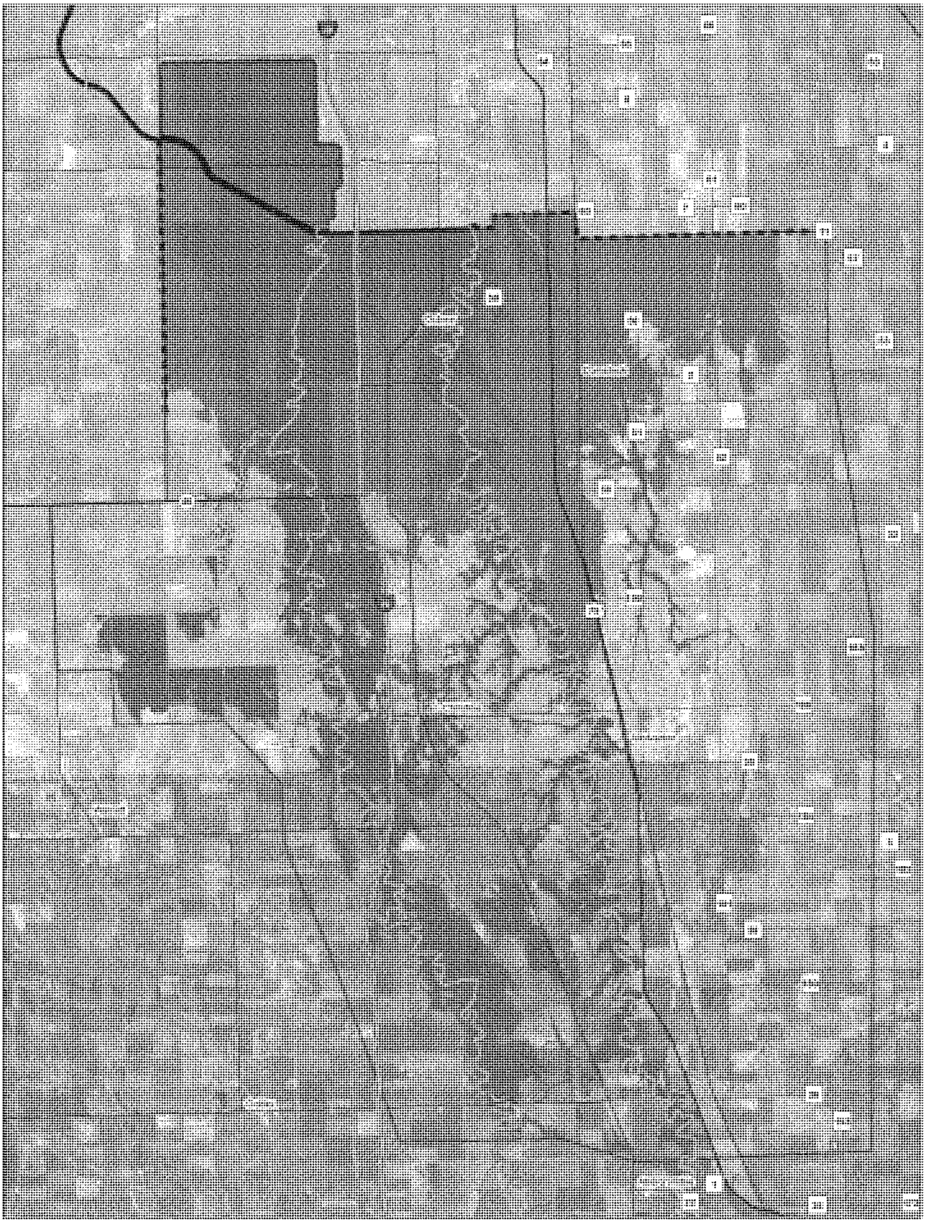


Figure 16

0.2% Existing (521,944 Acres)
LPP 0.2% (521,738 Acres)
Mapping Extent
Storage Area 1
LPP Diversion
LPP Tieback
Cities

Inundation Map for the Model Existing Conditions and With Project for 0.2-percent Chance Event in the Red River of the North - North of Diversion Works - LPP

0 2 4 8 12
Miles

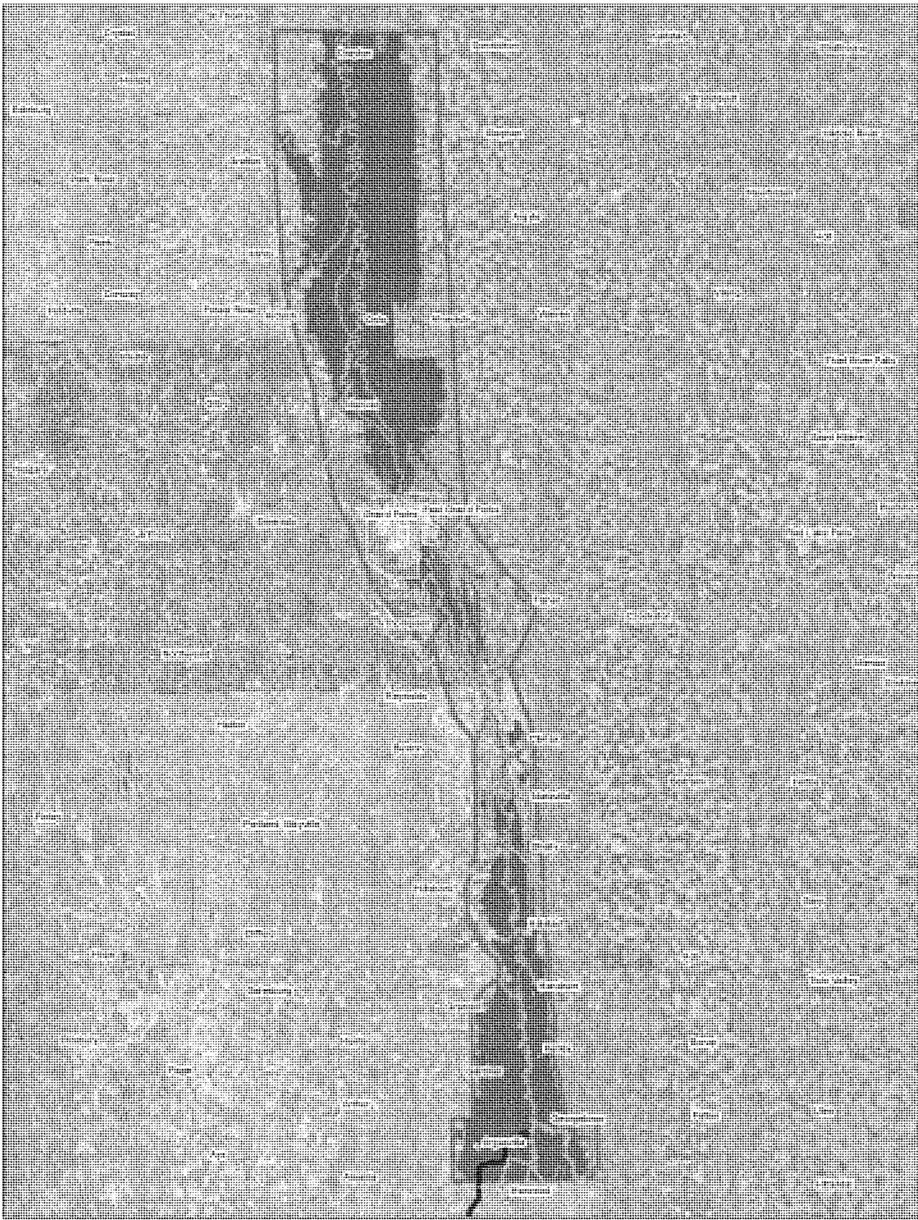


1% Existing (31,546 Acres)
LPP 1%(54,721 Acres)
Mapping Extent
Storage Area 1
LPP Diversion
LPP Tieback
Cities

Figure 17

Inundation Map for the Model Existing Conditions and With Project for 1-percent Chance Event in the Red River of the North - South of Diversion Works - LPP

0 0.3750.75 1.5 2.25
Miles

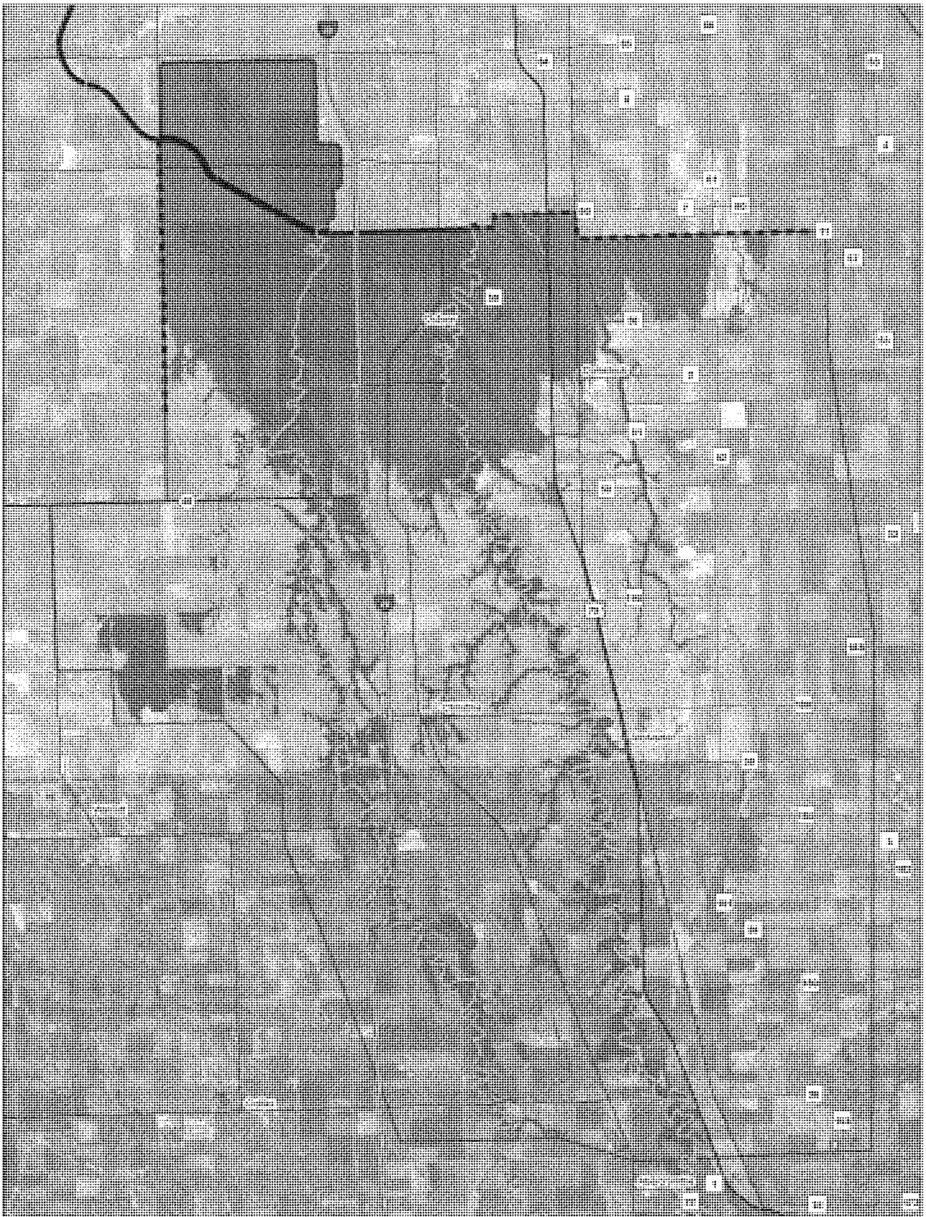


1% Existing (390,866 Acres)
LPP 1% (390,557 Acres)
Mapping Extent
Protection
Storage Area 1
LPP Diversion
LPP Tieback
Cities

Figure 18

Inundation Map for the Model Existing Conditions and With Project for 1-percent Chance Event in the Red River of the North - North of Diversion Works - LPP

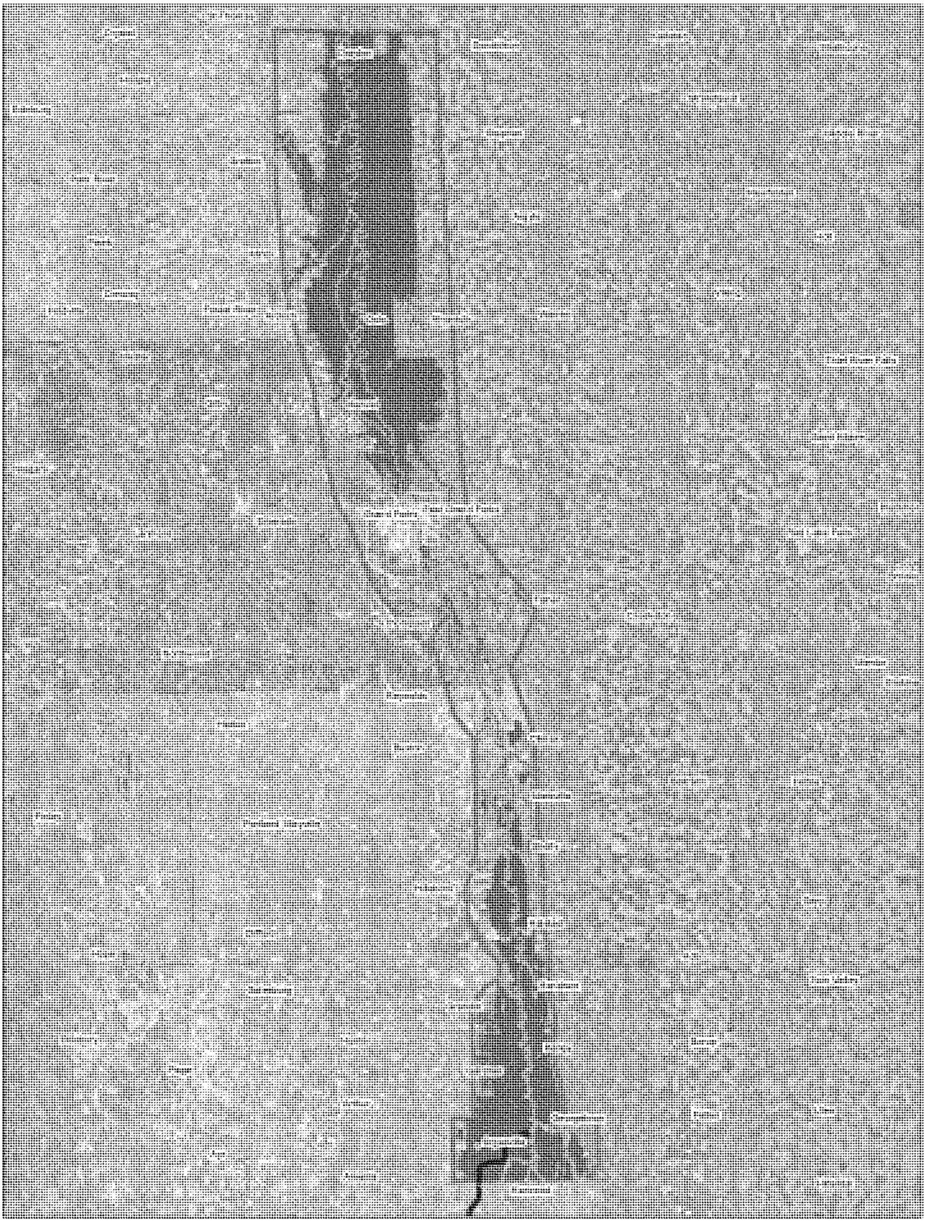
0 2 4 8 12
Miles



2% Existing (20,363 Acres)
LPP 2% (38,000 Acres)
Mapping Extent
Storage Area 1
LPP Diversion
LPP Tieback
Cities

Figure 19

Inundation Map for the Model Existing Conditions and With Project for 2-percent Chance Event in the Red River of the North - South of Diversion Works - LPP



2% Existing (347,158 Acres)
LPP 2% (346,696 Acres)
Mapping Extent
Protection
Storage Area 1
LPP Diversion
LPP Tieback
Cities

Figure 20

Inundation Map for the Model Existing Conditions and With Project for 2-percent Chance Event in the Red River of the North - North of Diversion Works - LPP

N

0 2 4 8 12
Miles

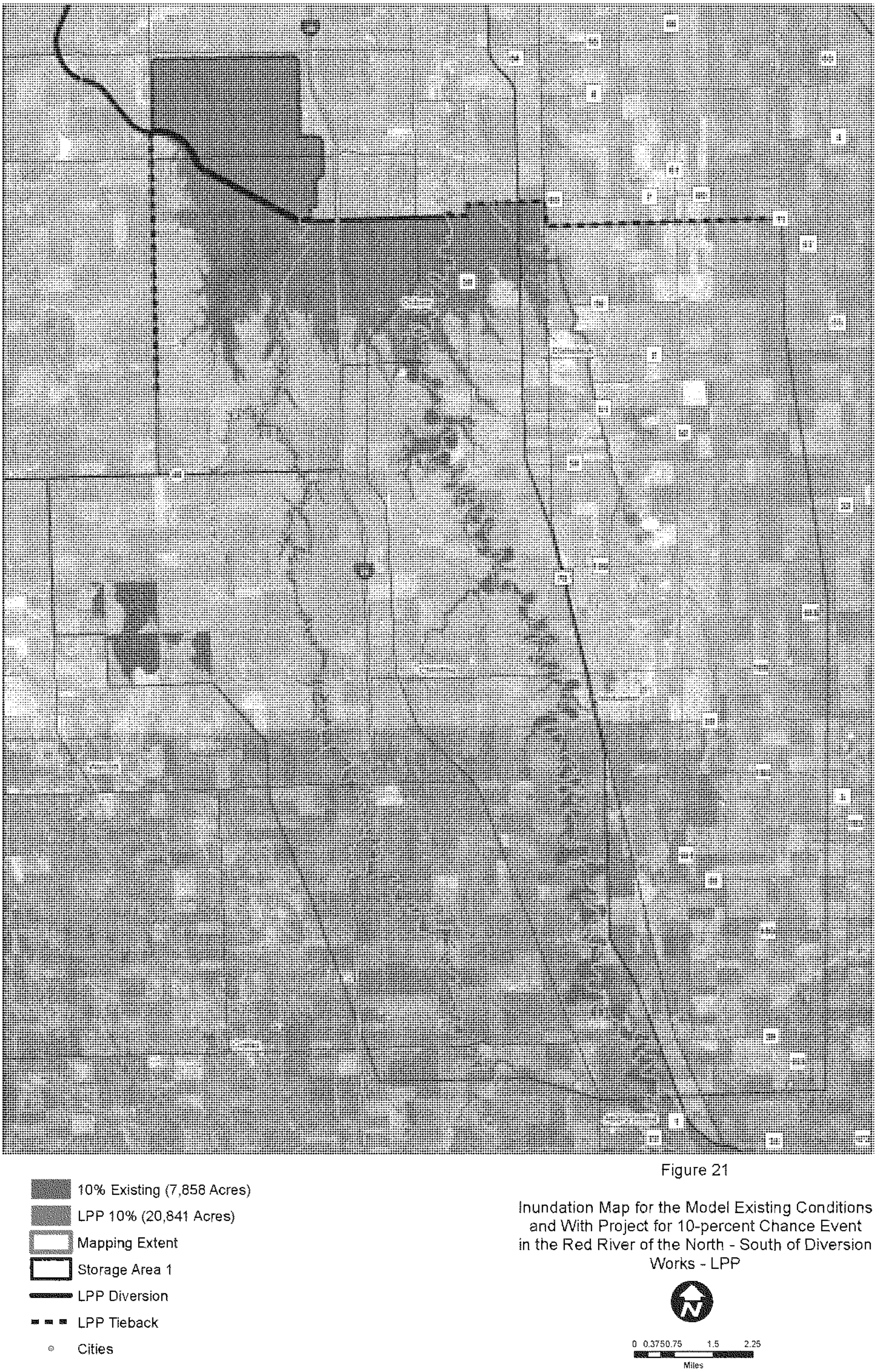
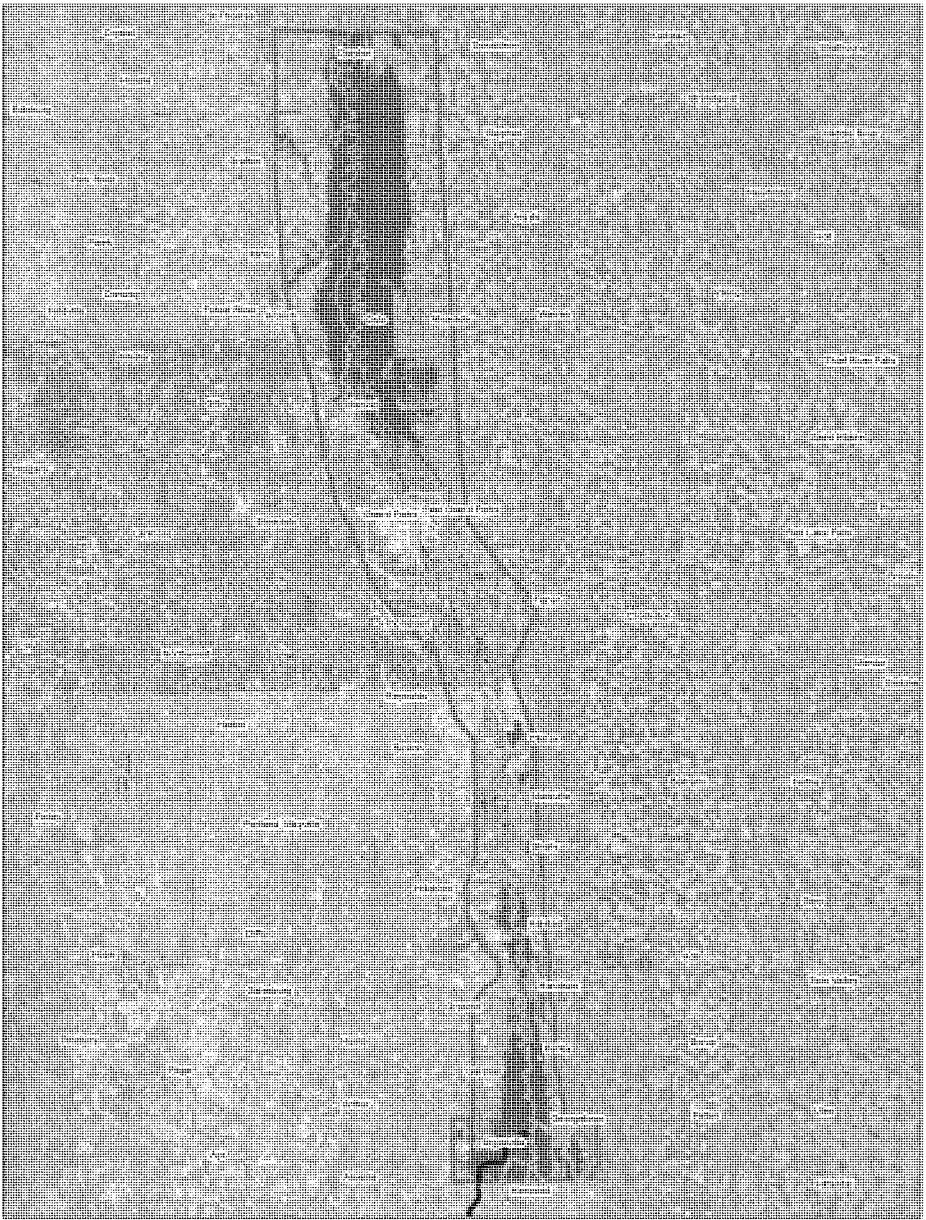


Figure 21

Inundation Map for the Model Existing Conditions and With Project for 10-percent Chance Event in the Red River of the North - South of Diversion Works - LPP



10% Existing (224,166 Acres)
LPP 10% (221,176 Acres)
Mapping Extent
Protection
Storage Area 1
LPP Diversion
LPP Tieback
Cities

Figure 22

Inundation Map for the Model Existing Conditions and With Project for 10-percent Chance Event in the Red River of the North - North of Diversion Works - LPP

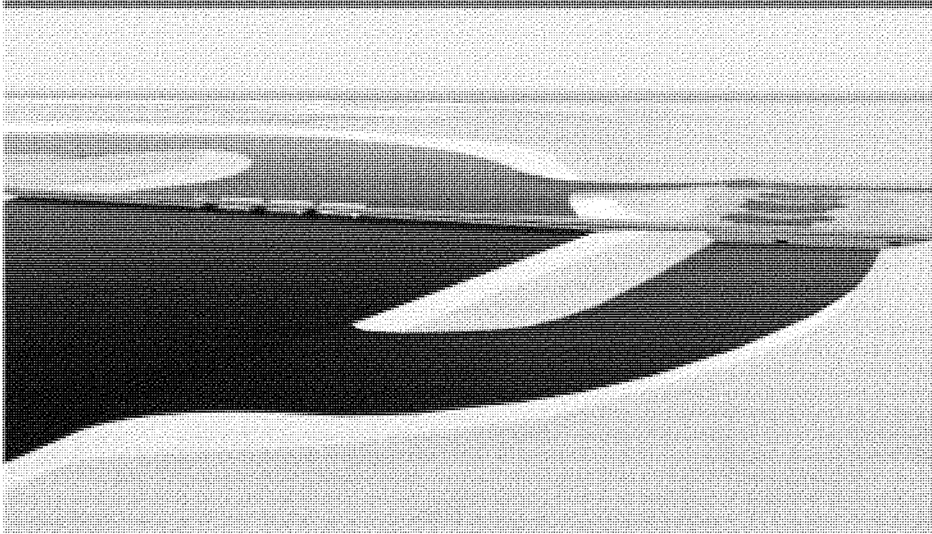
RED RIVER DIVERSION

FARGO-MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT

FEASIBILITY STUDY - PHASE 4

Volume 3

Appendices B-E



Report for the US Army Corps of Engineers
and the cities of Fargo, ND and Moorhead, MN

Prepared by:
Moore Engineering, Inc.; Houston Engineering, Inc.;
Barr Engineering Company; and HDR Engineering, Inc.

April 2011

RED RIVER DIVERSION

FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4

Report for the US Army Corps of Engineers and the cities of Fargo, ND & Moorhead, MN

Moore Engineering, Inc.; Houston Engineering, Inc.; Barr Engineering Company; HDR Engineering, Inc.

VOLUME 3

APPENDICES B - E

FINAL – Version April 14, 2011*

*Contents of this report are the same as the February 28, 2011 submittal unless otherwise specified.

RED RIVER DIVERSION

FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4

APPENDIX B –HYDRAULICS EXISTING CONDITION

Report for the US Army Corps of Engineers, and the cities of Fargo, ND & Moorhead, MN

By: HOUSTON ENGINEERING, INC.

REVISED: April 11, 2011

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E Existing Conditions 10-, 2-, 1-, and 0.2-Percent Chance Hydrographs
F Sensitivity Analysis – (Houston Engineering, Inc.)
G Weir Coefficient Sensitivity Analysis – (Barr Engineering)
H Model Peer Review and Model QA/QC Measures

B1.0 BACKGROUND AND OVERVIEW

The purpose of this study is to evaluate potential impacts from flood mitigation alternatives being considered as part of the U.S. Army Corps of Engineers (USACE) Fargo-Moorhead Metro Feasibility Study, Phase 4. This includes the Minnesota Diversion alternative (Federally Comparable Plan – FCP) and the North Dakota Diversion alternative (Locally Preferred Plan - LPP). To complete this analysis, an unsteady HEC-RAS model (v. 4.1) was created of the Red River of the North (RRN) and tributaries in the vicinity of Fargo, North Dakota and Moorhead, Minnesota.

The model was developed with sufficient detail to be used as a baseline for project design as well as benefit and impact analysis. The original model, completed after Phase 2 of the feasibility study, extended downstream to near Halstad, MN on the Red River. To further evaluate project impacts, the model was extended farther downstream to near Thompson, ND as part of Phase 3 of the feasibility study and to near Drayton, ND as part of Phase 4 of the feasibility study. The model was calibrated based on the 2009 spring flood. The 2006, 1997, and 2010 spring flood events were also created to verify the calibrated model. The 2006 flood event served as the pattern hydrograph for the synthetic flood events. The 10-, 2-, 1-, and 0.2-percent annual chance synthetic flood events were developed as the primary means to evaluate existing conditions, assist with project design, and to analyze potential impacts from flood mitigation alternatives being considered as part of the Fargo-Moorhead Metro Feasibility Study, Phase 4, including the FCP and LPP alternatives. This report updates previous versions of Appendix B unsteady Hydraulic Modeling dated as follows:

- August 31, 2009 – Draft
- October 1, 2009 – Revised Draft
- January 27, 2010
- February 12, 2010
- April 6, 2010 (Phase 2)
- July 30, 2010 (Phase 3)
- January 31, 2011 (Phase 4)
- February 28, 2011 (Phase 4)

B2.0 STUDY AREA

The hydraulic analysis completed for the Fargo-Moorhead Metro Feasibility Study spans approximately 325 miles of the Red River from Abercrombie, North Dakota through Fargo, North Dakota and Moorhead, Minnesota to the downstream end at Drayton, North Dakota. The City of Fargo is located in Cass County, North Dakota. The City of Moorhead is located in Clay County, Minnesota. Both communities are adjacent to the Red River of the North which forms the border between Minnesota and North Dakota. The communities are located approximately 453 river miles above the mouth of the Red River of the North at Lake Winnipeg, Manitoba.

The study area is highlighted in Figure B1. It includes the Red River of the North main stem and several tributaries. The Phase 2 study area originally extended north to River Mile 375 at Halstad, Minnesota. However, after failing to fully define downstream impacts (zero impact location) within the original study extents, the model was extended to River Mile 316 near Thompson, North Dakota (Phase 3). For Phase 4 of the feasibility study, the model was extended further downstream on the Red River to near Drayton, ND at approximately River Mile 198 and upstream on the Red River to near Abercrombie at approximately River Mile 524. The model was also extended farther upstream on the Sheyenne and Maple Rivers to better define the breakouts and flow distribution for these rivers. The downstream boundary locations in each of the phases (Halstad, Thompson, and Drayton) are at USGS stream gages as referenced in Appendix A – Hydrology.

Modeled tributaries to the Red River are the Wild Rice, Sheyenne, Maple, Elm, and Goose Rivers; Rose Coulee; and Cass County Drains 14, 27, 34, 53, and Richland County Drain 37 on the North Dakota side, and the Buffalo, Wild Rice, Marsh, Sandhill, and Red Lake Rivers; Heartsville Coulee; and Wolverton Creek on the Minnesota side as outlined below:

- The Wild Rice River, ND from its junction with the RRN upstream to USGS Gage 05053000 near Abercrombie, ND (River Mile 42.8).

- The Sheyenne River from its junction with the RRN upstream past the City of Kindred to the Gol Bridge (River Mile 75.2), including the West Fargo and Horace to West Fargo Diversion Channels.

- The Maple River from the confluence with the Sheyenne River to near Durbin, ND (River Mile 32.4).

- The Elm River from its confluence with the Red River to near Grandin, ND (River Mile 14.2) and the North Branch of the Elm River from its confluence with the Elm River to near Kelso, ND (River Mile 19.3). This model reach is for routing purposes only and does not contain channel bathymetry or hydraulic structures.

- The Goose River from its confluence with the Red River to USGS Gage 05066500 near Hillsboro, ND (River Mile 28.3). This model reach is for routing purposes only and does not contain channel bathymetry or hydraulic structures.

- Rose Coulee, Cass County Drain 27 (6.0 river miles), and Cass County Drain 53 (1.75 river miles) in south Fargo.

- Cass County Drain 14 (17.7 river miles), Cass County Drain 34 (7.9 river miles) and Richland County Drain 37 (12.1 river miles).

- The Buffalo River from its junction with the RRN upstream to USGS Gage 05062000 near Dilworth, MN (River Mile 34.7).

- The Wild Rice River, MN from its junction with the RRN upstream to USGS Gage 05064000 at Hendrum, MN (River Mile 7.8).

- The Marsh River from its junction with the RRN upstream to USGS Gage 05067500 near Shelly, MN (River Mile 14.4). This model reach is for routing purposes only and does not contain channel bathymetry or hydraulic structures.

- The Sandhill River from its junction with the RRN upstream to USGS Gage 05066500 near Climax, MN (River Mile 3.6). This model reach is for routing purposes only and does not contain channel bathymetry or hydraulic structures.

- The Red Lake River from its junction with the RRN upstream to USGS Gage 05080000 near Fischer, MN (River Mile 28.0).

- Heartsville Coulee from its junction with the Red Lake River to its junction with the Red River (River Mile 10.8)

- Wolverton Creek from its junction with the Red River to U.S. Highway 75 (River Mile 2.7).

B3.0 MODEL GEOMETRY DEVELOPMENT

B3.1 DATUMS

The model has been geo-referenced with the horizontal datum of NAD 1983 UTM Zone 14N, Foot_US. The vertical datum of the model is the North American Vertical Datum of 1988 (NAVD 1988).

B3.2 MODEL GEOMETRY CRITERIA

The unsteady HEC-RAS model geometry was developed by combining geometry from existing unsteady and steady state models with new geometry developed for the project. The following specific criteria were included in the Scope of Work (SOW) for this project:

- Overbanks for channel cross sections were based on the Red River Basin LiDAR collect (Reference 8), or other LiDAR collects as noted in Table B1.

- Channel bathymetry for the reach from River Mile 440.0 to 470.2 was based on RRN soundings that were obtained for Phase 1 of this study. For areas outside the reach defined above, the channel bathymetry was based on the cross sections from existing HEC-RAS and HEC-2 models.

- The model geometry defines the effective flow limits between the river overbanks and the storage areas.

- In the rural areas, storage areas were generally defined as one square mile sections with the storage volume relationship based on the LiDAR data. However, larger storage areas were used where it was deemed appropriate using engineering judgment.

- In the urban areas, the storage areas were based on controlling road profiles and other topographic features with the storage volume relationship based on the most recent LiDAR data.

- Lateral structures and storage area connections have been defined as weirs following section line roads or other controlling roads or topographic features. Road profiles were obtained from the LiDAR data where more detailed information is not available. Detailed surveys were used where available. The use of detailed surveys was limited and generally occurred where existing HEC-RAS model geometry was incorporated into the unsteady HEC-RAS model geometry.

- Culverts three feet and larger in diameter have been included in the lateral structures and storage area connections, where appropriate. For most areas, the culvert locations and size were determined using field reconnaissance for this project. Culvert inverts were approximated using LiDAR data and road elevations and estimates of the cover on the culverts. When surveyed culvert data or data from construction drawings was available, this information was used. Table B1 identifies the level of detail that was utilized for the storage area connections for the various model reaches.

- Time constraints and the large scale of the model expansion did not allow field evaluation of culverts throughout the entire system. Culverts between Perley and Drayton were estimated and separated into one of two categories, small and large. To identify the assumed culverts in the model, the culverts were modeled with unique sizes. Small culverts were modeled as 2.9' x 2.9' box culverts and large culverts were set as 5.9' x 5.9' box culverts. The small culverts were used to represent typical ditch and field swale conveyance and the large culverts were used to represent larger, more concentrated ditch and drain conveyance.

B3.3 SOURCES OF HEC-RAS GEOMETRY DATA

Where available, geometry from existing models was used to develop the HEC-RAS model geometry for this study. Table B1 summarizes the model extent for the various streams along with the sources for the model geometry. The primary source for cross section and structure data was a combination of existing hydraulic models, bridge plans, and field survey data from previous projects. The primary source for overbank cross section and storage area geometry was the Red River Basin LIDAR data (Reference 8).

Figure B2 shows the combined HEC-RAS model geometry. Figures B3-B18 show the model geometry in greater detail.

Table B1 - Sources of HEC-RAS Geometry Data

Stream	Extent	River Miles	Cross Section Reach	Cross Section and Hydraulic Structure Data Source	Overbank Cross Section and Storage Area Data Source	Level of Detail/Quality of Source Data (High, Medium, Low)
Red River of the North	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Red River of the North	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Red River of the North	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Red River of the North	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Red River of the North	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sheyenne River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sheyenne River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cass County Drain 14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Maple River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table B1 - Sources of HEC-RAS Geometry Data

Stream	Extent	River Miles	Cross Section Range	Cross Section and Hydraulic Structure Data Source	Overbank Cross Section and Storage Area Data Source	Level of Detail/Quality of Source Data (High, Medium, Low)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

B3.4 MODEL NOMENCLATURE

The cross section naming convention used for the HEC-RAS model is based on the distance in feet above the mouth of the stream. Specifically, cross sections on the Red River are referenced above its outlet into Lake Winnipeg. Tributary cross sections are referenced in distance above their confluence with the Red River. Model reaches are based on abbreviations of the stream name and common landmarks or tributaries. Storage areas (SA) and storage connections (SC) are generally referenced to the nearest stream (WRR = Wild Rice River) or town (Fgo = Fargo). There are some exceptions to this naming convention, such as near portions of the Sheyenne and Maple Rivers where no naming convention was used.

B3.5 MODEL GEOMETRY PARAMETERS AND CALIBRATION

The HEC-RAS model was calibrated to the 2009 spring flood event using high water mark and gage data obtained from city, county, and federal agencies. The 2009 spring flood event was chosen for the calibration event because it was the flood of record and was well documented by high water marks and stream gage data. The original model (Phase 2) extended downstream to near Halstad, MN on the Red River. To further evaluate project impacts, the model was extended farther downstream to near Thompson, ND (Phase 3) and Drayton, ND (Phase 4). Emergency flood protection measures, as highlighted in Figure B19 were added to the model geometry as levees for calibration. Calibration was accomplished by adjusting Manning's "n" values, bank stations, overbank reach lengths, and ineffective flow limits based on aerial photographs taken during the 2009 and 1997 floods. Figure B20 shows the calibrated water surface profile for the Red River during the 2009 flood. It includes the peak stages along with high water marks. The model was verified using the spring floods of 2006, 1997, and 2010. Figures B20-B23 show the verification model water surface profiles for the Red River during the 2006, 1997 and 2010 floods. Figures B37-B40 show the locations of high water marks from the 2009, 2006, 1997, and 2010 floods that were utilized for model calibration and verification. High water marks and stream gage data is generally limited to the Red River main stem and major tributaries and is not available for storage connections and breakout reaches. This limited our ability to calibrate and verify the flow through these areas, however, the sensitivity analysis that was performed (see Exhibit F) shows the model results and impacts are not overly sensitive to shifts in discharge and timing between tributaries.

3.5.1 Boundary Conditions

Starting water surface elevations were obtained from rating curves based on high water data; USGS rating curves at Drayton, ND; and the results of the USACE Regional Red River Flood Assessment Report (Reference 1).

3.5.2 Manning's "n" Values

Manning's "n" values were primarily taken from the source models used for the unsteady model development. They were verified using aerial photos and land use GIS data. Some adjustment to the Manning's "n" values was done during model calibration. Table B2 summarizes the Manning's "n" values used for the various stream reaches:

Table B2 – Manning's "n" values

Watercourse	Channel	Overbank
Red River of the North	0.045	0.045 – 0.16
Wild Rice River (ND)	0.035-0.045	0.05-0.13
Sheyenne River	0.035-0.052	0.04-0.10
Richland County Drain 37	0.04	0.04
Cass County Drains 14 and 34	0.035	0.04
Maple River	0.04	0.04-0.08
Elm River and North Branch Elm River *	0.045	0.09
Goose River *	0.045	0.07-0.12
Rose Coulee/Cass County Drains 27 and 53	0.035-0.045	0.04-0.06
Buffalo River	0.04	0.065-0.135
Wolverton Creek	0.045	0.08
Wild Rice River (MN)	0.045	0.09-0.11
Marsh River *	0.045	0.07-0.12
Sandhill River *	0.045	0.12
Red Lake River	0.045	0.055-0.12
Heartsville Coulee	0.012-0.07	0.045-0.12

*Model reaches are for routing purposes and do not contain channel bathymetry.

3.5.3 Weir Coefficients

After a detailed sensitivity analysis (Exhibit F) and discussions with the Hydrologic Engineering Center (HEC) and the project team, weir coefficients were set to 1.0 for storage connections and lateral structures to better represent the conveyance of flow through the storage areas. A weir coefficient memorandum prepared as part of the sensitivity is included in Exhibit G. Some connections and lateral structures had frequently overtopping weirs with very low elevations at or near stream crossings. The low weirs caused instabilities in the model due to excessive conveyance. Therefore, a weir coefficient of 0.5 was used to provide a more reasonable and stable discharge across the weir. Inline structure weir coefficients maintained the model default value of 2.6.

3.5.4 Calibration Tolerances

The models were generally calibrated to a tolerance of within one-half foot of the 2009 spring flood high water marks which matches FEMA's criteria for hydraulic model calibration (Reference 19). Exceptions included the Wild Rice River, ND area and the Oakport, MN area where this tolerance could not be met. This is attributed to the unique partial ice cover conditions and breakout flows that occurred in these areas during the 2009 spring flood event. Exhibits A, B, C, and D contain discharge hydrograph comparisons for select locations from the 2009 flood calibration, and the 2006, 1997, and 2010 spring flood verifications, respectively. Similar to the 2009 flood calibration event, the 2006, 1997, and 2010 flood verification events generally met the calibration tolerance of matching within one-half foot of measured high water marks.

3.4.5 Unsteady Flow Analysis Settings and Parameters

The simulation time of the synthetic models start 15MAR2006 and end 01MAY2006. 2006 was used since the balanced hydrographs were patterned after the 2006 flood event. The historic event start date varied because of the variability in crest date depending on the event. Typically the historic models began 10 days before the respective crest and ran for 1.5 months. The Hydrograph Output Interval and Detailed Output Intervals were both set at 12 Hours. The computation interval began with a warm up time step of 30 seconds and had an actual model run time computation of 5 minutes. A sensitivity analysis was conducted to evaluate model results with a shorter computation interval. A 1 minute interval was used for this. The model took significantly longer to run, however the output results were within 0.01 feet of the results with a 5 minute interval. Due to the complexity of the model, the Water Surface Calculation Tolerance was changed from the default of 0.02 feet to 0.03 feet. Also, the Storage Area Elevation Tolerance was changed from the default of 0.05 feet to 0.1 feet. A sensitivity analysis was conducted to determine the effects of the Storage Area Elevation Tolerance change. It was set back to the default and re-computed. The model produced many "failure to converge" warnings while using the smaller tolerance (0.05'). After a long computation run time, the resulting water surface elevation error averaged 0.07 feet (with the smaller tolerance). This was very similar to the error with the setting at 0.1 feet. Therefore, the Storage Area Elevation Tolerance used in the model project seemed reasonable. The Lateral Structure flow stability factor was changed from the default of 2 to 3. The Gate flow submergence decay exponent was changed from the default of 1 to 3. Table 3 shows the varying parameters in tabular form.

Table B3 – HEC-RAS Unsteady Computation and Option Tolerances

Unsteady Flow Options	Default	Model
Theta (implicit weighting factor) (0.6-1.0)	1	1
Theta for warm up (implicit weighting factor) (0.6-1.0)	1	1
Water surface calculation tolerance (ft)	0.02	0.03
Storage Area elevation tolerance (ft)	0.05	0.1
Flow calculation tolerance (optional) (cfs)	n/a	n/a
Maximum number of iterations (0-40)	20	20
Number of warm up time steps (0-200)	0	50
Time step during warm up period (hrs)	0	0.00833
Minimum time step for time slicing (hrs)	0	0
Maximum number of time slices	20	20
Lateral Structure flow stability factor (1.0-3.0)	2	3
Inline Structure flow stability factor (1.0-3.0)	1	1
Weir flow submergence decay exponent (1.0-3.0)	1	1
Gate flow submergence decay exponent (1.0-3.0)	1	3
DSS Messaging Level (1 to 10, Default = 4)	4	4
Maximum error in water surface solution (Abort Tolerance)	100	100

B4.0 MODEL HYDROGRAPH DEVELOPMENT

The initial phase of this feasibility study was completed for the U.S. Army Corps of Engineers and cities of Fargo, ND and Moorhead, MN in August, 2009. The study utilized Phase 1 hydrology developed by the U.S. Army Corps of Engineers and a steady-state HEC-RAS model for the design of project alternatives including diversion channels and hydraulic structures. Similarly, the Phase 2 and Phase 3 studies utilized the steady-state HEC-RAS model for the design of project features. The Phase 2 and Phase 3 studies also utilized the unsteady HEC-RAS model to evaluate project impacts associated with the proposed diversion alternatives related to the loss of floodplain storage and changes to timing as a result of the proposed diversion channels. Phase 4 of the feasibility study utilizes the unsteady HEC-RAS model for project design and impact evaluation due to the need to consider the staging and storing of water to mitigate project impacts associated with the Locally Preferred Plan (LPP). This model hydrograph development narrative will reference examples from the 2009 historic flood event since it was used for primary calibration. Descriptions of the unique characteristics of the 2009 event and the additional 1997, 2006, and 2010 historic flood verification events will follow in subsequent sections. The methodology used for matching balanced hydrographs for the synthetic events is described in Section B4.4 of this report.

B4.1 UNSTEADY MODEL INFLOWS

Model inflows for the unsteady HEC-RAS model consist of nearly 80 inflow hydrographs including upstream boundary condition inflow hydrographs, lateral hydrographs, and uniform lateral hydrographs. Some originate at USGS gage locations, others are ungaged local inflows and a few are base flows required to maintain model stability. The hydrograph development procedures used for historic events and synthetic events are similar. An inflow hydrograph was inserted at the upper boundary condition of each river reach and intermediate hydrographs were added to help match the target hydrographs. USGS observed hydrographs along the Red River were matched for the historic events and balanced hydrographs were the targets for synthetic events. Additional balanced hydrograph explanation is provided in Section 6 of Appendix A-Hydrology. The observed USGS gage locations and balanced hydrograph locations along the Red River are shown in Figure B24.

B4.2 UPSTREAM FLOW HYDROGRAPHS

The unsteady HEC-RAS model geometry was extended upstream on the Red River and upstream on most of the tributaries to locations with input data from USGS stream gages. This provides the model with sufficient upstream boundary condition inflow data with the exception of those areas where breakouts occur near the upstream gages (discussed in detail in subsequent sections of this report). The following are upstream boundary condition inflow hydrograph locations along with their respective modeling methodologies:

4.2.1 Red River

The original model (Phase 2 and 3) extended upstream to USGS gage 05051522 at Hickson, ND (XS 2563754). The drainage area here is approximately 4,300 square miles. Hickson was a sufficient upstream boundary until the upstream staging feature was added to the LPP in Phase 4. It was then necessary to extend the model an additional 38 river miles upstream to provide geometry for the staging volume and upstream boundary condition. The upstream boundary of the Red River portion of the model is now at cross section 2764835, adjacent to USGS Gage 05053000 on the Wild Rice River at Abercrombie, ND. The next upstream gage on the Red River is at Wahpeton, ND, approximately 25 miles further upstream.

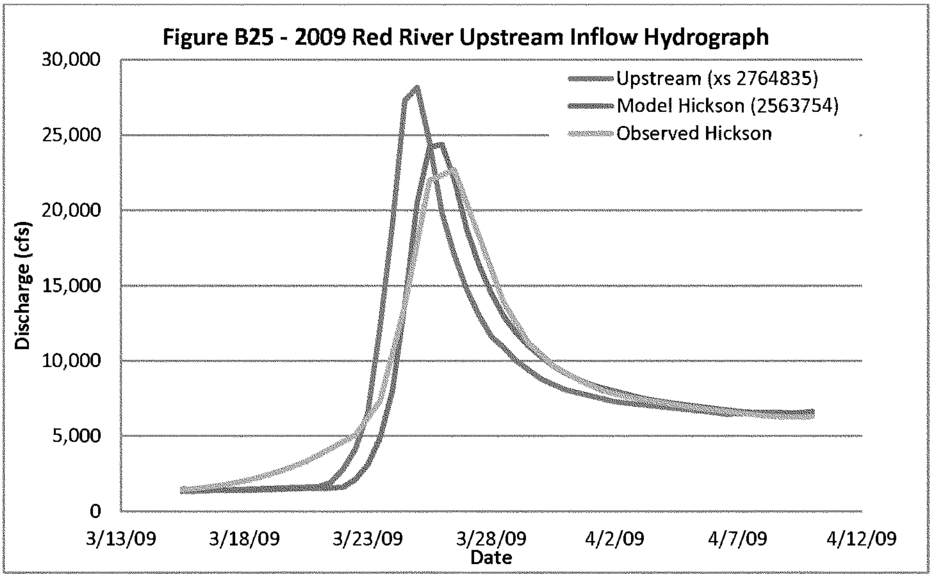
For the extended model, the Red River inflow hydrograph was adjusted so that the routed hydrograph to Hickson would match the observed hydrograph at the Hickson gage. Figure B25 below shows the actual upstream hydrograph in comparison to the Hickson gage for the 2009 event. Notice the modeled hydrograph is actually higher than the observed hydrograph. The modeled hydrograph was increased based on the calibration fit at the Fargo gage. It was justified by accounting for a level of uncertainty within the gaged data. The USGS records actual stage measurements and then they calculate the discharge based on a given rating curve. The USGS rates the quality of the calculated discharge with a quality code as shown in Table B3.

Table B4 – USGS Discharge Measurement Quality Codes

Discharge Measurement Quality Code

Code	Description	
E	Excellent	The data is within 2% (percent) of the actual flow
G	Good	The data is within 5% (percent) of the actual flow
F	Fair	The data is within 8% (percent) of the actual flow
P	Poor	The data are >8% (percent) of the actual flow

The first two-field measurements during the 2009 flood at the Hickson gage were rated "poor" (3/25 and 3/28). The third measurement, after the crest, was rated "fair". This supported the assumption that the actual discharge in the Red River during the crest could be greater than 8% different than the discharge reported by the USGS. The same discharge measurement quality codes were observed and accounted for at each of the gaged locations along the Red River and the contributing tributaries. Exhibits A, B, C and D display Red River modeled hydrographs in comparison to the USGS observed hydrographs and gage quality for the 2009, 2006, 1997 and 2010 events respectively. Additional detail related to the specific gages is noted in Section B5.0 of this report.



4.2.2 <u>Wild Rice River, ND</u>

The hydrograph at the upstream end of the Wild Rice River, ND reach was supplied directly from USGS Gage 05053000 at Abercrombie, ND. The Wild Rice River Watershed consists of approximately 2,080 square miles which is nearly 30 percent of the total drainage area upstream of the Fargo/Moorhead project area.

4.2.3 <u>Sheyenne River</u>

The Sheyenne River contributes a significant amount of runoff to the Red River downstream of the Fargo/Moorhead project area. The upper end of the Sheyenne basin is regulated by Baldhill Dam. The lower end flows uncontrolled through a perched and meandering system. Because the channel is perched, discharges in excess of the channel's capacity are conveyed out of the channel and into the floodplain. These breakout flows either re-enter the system further downstream or become conveyance in a completely different system. Because of the perched channel, the 2%, 1% and 0.2% chance flood discharges are nearly all the same at approximately 4,600 cfs upstream of Horace, ND.

The upper end of the model on the Sheyenne River is upstream of Gol Road, approximately three miles south of Kindred, ND. In 2009, the USGS placed a gage at this location to collect additional information on breakout flows from the Sheyenne River between Gol Road and Kindred. Breakouts from the left bank become part of Cass County Drain 34 and Cass County Drain 14 which later flow into the Maple River. The Maple River joins with the Sheyenne River downstream of West Fargo. Breakouts from the right bank of the Sheyenne River between Gol Road and Kindred exit the system through Richland County Drain 37. These breakout flows become part of the Wild Rice River system and contribute upstream of the project area.

To account for breakout flows in the Sheyenne River system, a hydrograph was inserted into the model upstream of Gol Road. Through an iterative process of adding water and allowing the model geometry to quantify the breakout flows, the hydrograph in the system was reasonably matched at USGS Gage 05059000 at Kindred. The Kindred gage has a much longer history than the USGS Gage 05058980 at Gol Road. It has provided discharge measurements since 1949 and stages since 2000. Breakouts also occur in the system between Kindred and Horace. These breakouts typically bypass Horace and enter the Sheyenne River system either through Cass County Drain 21c or just upstream of Interstate 94. The stage and discharge measurements through the Sheyenne River system from Kindred through West Fargo are very susceptible to ice conditions which induce stage increases and significant breakout flows. Therefore, an average match of discharge at the various gages was determined to be acceptable. Figure B26 is a schematic of the Sheyenne River corridor displaying potential breakout locations along the Sheyenne River as well as inflow hydrograph locations.

4.2.4 Maple River

The Maple River system, once completely unregulated, now receives some flood reduction benefit from storage provided by the Maple River Dam (2009-present). The Maple River has a perched channel similar to that of the Sheyenne River. The Maple River reach of this model extends to Durbin, ND, upstream of a known breakout location. Similar to the Sheyenne River reach between Gol Road and Kindred, the hydrographs at the upper end of the Maple River were inserted into the model near Durbin. These flows were increased, allowed to break out, and the remaining modeled hydrograph was compared to USGS Gage 0506000 on the Maple River near Mapleton. To make this area more complex, two large drainage areas contribute to the system between Durbin and the Mapleton gage. If all inflows were added to the system at Durbin, excessive flows would be diverted at the breakout location. To compensate for this, the inflow hydrograph was divided proportionally between Swan Creek (129 square miles), Buffalo Creek (192 square miles), and the local drainage area between the Maple River Dam and Durbin (208 square miles). Since the 2009 flood event was used for calibration, the hydrograph from USGS Gage 05059715 on the Maple River (outlet of dam) was routed to the upper end of the model. This provided an approximate 1,000 cfs base flow discharge during the first peak of the 2009 flood. The dam hydrograph routed to Mapleton (through the model) was then subtracted from the USGS observed hydrograph near Mapleton. The missing hydrograph was distributed between the three above referenced drainage areas until the hydrograph matched at the Maple River gage near Mapleton. Figure B27 shows the drainage areas, inflow locations, and breakout paths for the Maple River.

The other three historic events occurred prior to the construction of the Maple River Dam. Since the dam outlet hydrograph was unavailable, the observed Maple River discharge hydrograph at USGS Gage 05059700 near Enderlin was used as the inflow hydrograph at the upstream end of the Maple River at Durbin. An iterative process was used to determine an appropriate routing from Enderlin to Durbin, then the model routed the hydrograph from Durbin to Mapleton. This hydrograph was subtracted from the observed hydrograph at the Mapleton gage. As with the 2009 calibration, the missing local hydrograph was distributed between the ungaged areas including: Swan Creek, Buffalo Creek, and the local drainage area between Enderlin and Mapleton. The Enderlin hydrograph and local ungaged hydrographs combine to form the observed hydrograph at the Mapleton gage and breakout flows. The breakout flows are conveyed overland (through storage areas) to Cass County Drain 14 which contributes to the Sheyenne River.

4.2.5 Rush River

The Rush River model geometry was not developed as a detailed river reach. The lower end of it was modeled using storage areas and storage connections simulating the river and drain channels. In Phase 4, the storage areas were extended three to four miles west of the proposed LPP alignment to provide a more consistent geometry upstream of the project for existing conditions and with- project conditions. For hydrograph development purposes, the Rush River area was sub-divided into four basins. Each of the four sub-basins has approximately the same shape and a similar size. Therefore, all of the hydrographs reference USGS Gage 05060500 on the Rush River at Amenia with varying ratios based on size. The first basin, composed of approximately 116 square miles, is upstream of the USGS gage at Amenia, ND. This basin used the Amenia gage hydrograph with an assumed one day route to the storage area input location. The Rush River area between the Amenia gage and the Sheyenne River has a drainage area of approximately 45 square miles. The Lower Rush River contributes approximately 50 square miles. Cass County Drain 13 was also included in the Rush River calculations contributing 58 square miles. Each of the four hydrographs have been inserted as a ratio of the Amenia gage in the appropriate storage area on the west side of the model. Figure B28 shows the Rush River area inflow locations and drainage areas.

4.2.6 Buffalo River

The hydrograph at the upstream end of the Buffalo River reach was supplied directly from USGS Gage 05062000 at Dilworth, MN. The Buffalo River Watershed at Dilworth consists of approximately 975 square miles, and contributes to the system directly downstream of the Fargo/Moorhead project area.

4.2.7 Elm River

The Elm River Watershed consists of approximately 515 square miles. The National Weather Service (NWS) provided estimated hydrographs from their flood prediction model for the 2006 and 2009 flood events for the North Branch of the Elm River and the Elm River at Highway 81 (just downstream of Interstate 29). The estimated North Branch hydrograph accounts for approximately 124 square miles at a location near Kelso, ND. The Elm River (south branch) near Grandin, ND, contributes runoff from approximately 338 square miles. Another 53 square miles between the measured locations and the Red River was accounted for in the local runoff calculations.

To assist with modeling efforts, stream gages were placed at the two Elm River locations (described above) for the 2010 flood event. Data was obtained and utilized in the 2010 verification model. The estimated NWS hydrographs were used for the 2006 and 2009 events. Since estimated data was unavailable for the 1997 event, USGS Gage 05061500 on the South Branch of the Buffalo River at Sabin, MN was used with ratios based on respective drainage areas. The drainage area at this gage is 454 square miles.

4.2.8 Wild Rice River, MN
The hydrograph at the upstream end of the Wild Rice River, MN reach was supplied directly from USGS Gage 05064000 at Hendrum, MN. The Wild Rice River Watershed at Hendrum consists of approximately 1,560 square miles. It is approximately seven river miles upstream of the Red River.

4.2.9 Goose River
The Goose River reach was developed as a simple routing reach. As described above in the geometry section, the model was extended upstream to USGS Gage 05066500 at Hillsboro, ND. The Goose River at Hillsboro contributes approximately 1,093 square miles to the system.

4.2.10 Marsh River
The Marsh River reach was developed as a routing reach. The model was extended upstream to USGS Gage 05067500 near Shelly, MN. The Marsh River near Shelly contributes approximately 220 square miles to the system in addition to breakout flows from the Wild Rice River near Ada, Minnesota.

4.2.11 Sand Hill River
The Sand Hill River reach was developed as a routing reach. The model was extended upstream to USGS Gage 05069000 at Climax, MN. The Sand Hill River at Climax contributes approximately 420 square miles to the system.

4.2.12 Red Lake River
The Red Lake River was extended upstream as a routing reach to USGS Gage 05080000 at Fisher, MN. The Red Lake River at Fisher contributes approximately 5,680 square miles to the system. The Fisher gage is relatively new. It has been recording discharge since 1999. USGS Gage 05079000 on the Red Lake River at Crookston (5,270 SM), upstream of the Fisher gage, has a longer measurement record tracing back to the early 1900's. Records from the Crookston gage were also compared when obtaining historic flow data.

4.2.13 Tributaries Downstream of Grand Forks
The model reach downstream of Grand Forks contains less detail than the upstream reach since existing model geometry was utilized that does not extend up the tributaries. Therefore, the inflow hydrographs between Grand Forks and Drayton were simplified. For hydrograph development during calibration, the Grand Forks hydrograph was subtracted from the Drayton target hydrograph. The resulting hydrograph was proportionally distributed amongst the intermediate drainage areas to create a hydrograph that corresponds to each of the tributaries. The inflow hydrographs were inserted at the tributary locations on the Red River. Tributary reaches were not created and the gages on the tributary rivers were not used. This methodology was originally used for the historic events as well as the synthetic events in Phase 4 for the January 31, 2011 submittal.

Subsequent to the January 31, 2011 submittal, the historic event calibration and verification hydrographs between Grand Forks and Drayton were improved to include gaged tributary data. The Phase 4 synthetic design events still use the proportionally distributed, ungaged hydrographs. Documentation on the watersheds between Grand Forks and Drayton for the historic events is as follows:

- Cole Creek – Cole Creek conveys runoff from approximately 307 square miles south and west of Thompson, ND to a location near USGS Gage 05082500 at Grand Forks. This area remains part of the ungaged drainage area computations.

- Grand Marais River – The Grand Marais River system includes approximately 530 square miles of drainage between Grand Forks and Oslo on the Minnesota side of the Red River. This area also remains part of the ungaged drainage area computations.

- Turtle River – A small portion of the Turtle River (311 SM) is documented with USGS Gage 05082625 data near Arvilla, ND. The remaining 624 square miles is part of the ungaged calculations.

- Forest River – 620 square miles of the Forest River is measured at USGS Gage 05085000 at Minto, ND. The remaining 315 square miles is accounted for in the ungaged hydrographs.

- Snake River – The upper portion of the Snake River is measured at USGS Gage 05085450 near Warren, MN. Here, 176 square miles of runoff is reported. The remaining 612 square miles of the Snake River is part of the ungaged contributions between Oslo, MN and Drayton, ND.

- Middle River – The Middle River is measured at USGS Gage 05087500 at Argyle, MN with 255 square miles of drainage area. The Middle River is a tributary of the Snake River.

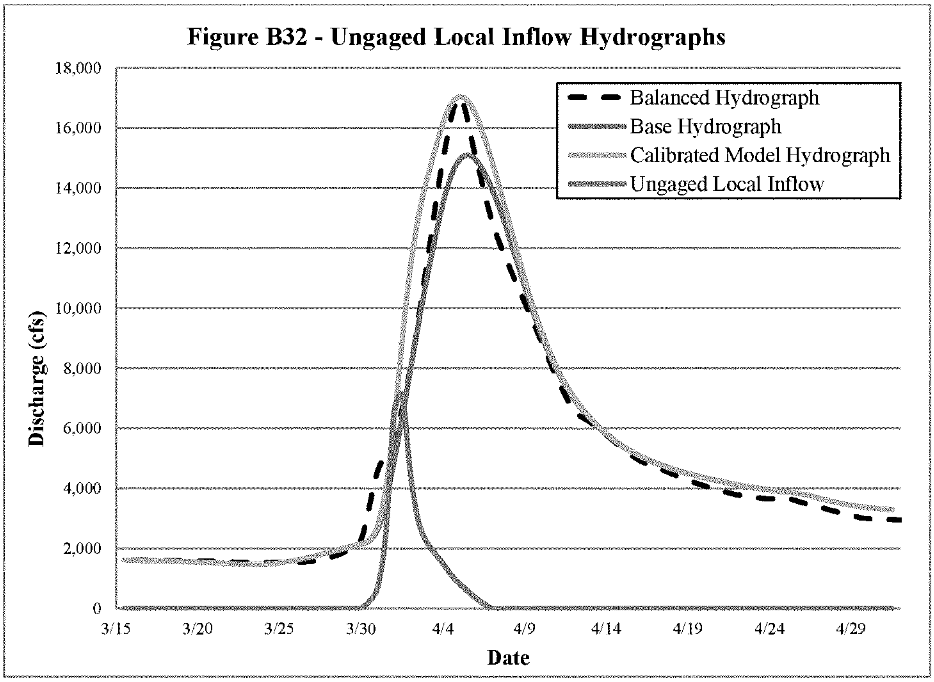
- Park River –USGS Gage 05090000 on the Park River at Grafton measures approximately 695 square miles of drainage area. The remaining 292 square miles is included in the ungaged drainage calculations.

- Tamarac River – The Tamarac River, in Minnesota, includes ungaged drainage from approximately 423 square miles. This contribution enters the Red River just upstream of Drayton, ND.

B4.3 UNGAGED INFLOW HYDROGRAPHS

As discussed above, observed inflow hydrographs were inserted into the model at the upstream ends of tributaries and other large contributing areas. Local inflow hydrographs were estimated to account for inflow downstream of gage locations. They were used to supplement the observed inflows between calibration points. For example, upstream of the Fargo gage, the Hickson and Abercrombie gages provide observed inflows at the upstream ends of the Red River and Wild Rice River respectively. Between these two gages and the Fargo gage there is approximately 384 square miles that is divided into twelve sub-basins. Figure B29 displays a table and series of hydrographs representing typical local inflows upstream of the Fargo gage. The table shows the name given to each sub-basin, the location it was placed in the model and the drainage area. As displayed in the hydrograph example, it was assumed that the duration of the local inflow hydrographs are the same regardless of the size of contributing area. Figure B30 shows a detailed spatial extent of the sub-basins upstream of Fargo. For ease in converting flow files from existing conditions to LPP and FCP conditions, sub-basin delineation was adjusted so the same areas could be to be utilized for all conditions without modifications. The LPP model hydrographs can be used without making changes. “WLVSA1” (Wolverton storage area 1) was split along the FCP alignment. The portion west of the alignment was assumed to drain to the Red River, the east half was inserted into the FCP diversion. A larger scale local inflow drainage area map for the entire model is presented in Figure B31

The “base hydrograph” run includes routing the Hickson and Abercrombie hydrographs to the Fargo gage. This provided a starting point for determining the local inflows. The base hydrograph was then subtracted from the observed target hydrograph at the Fargo gage to obtain a local inflow hydrograph to be distributed throughout the upstream drainage area. An iterative process was used to account for the hydrograph routing time to the Fargo gage. The hydrograph in Figure B32 below displays the results of this procedure for the 10-percent chance flood event aiming to match the provided balanced hydrograph at Fargo. The final calibrated model hydrograph is shown in green.



A similar calibration methodology was used to account for local inflows between the gaged hydrographs at Fargo and Halstad. Here, local drainage areas also extend up the Sheyenne River, Maple River, Rush River, Buffalo River, Wild Rice River, MN, and Elm River totaling approximately 1000 square miles. The third calibration location between Halstad and Thompson included 280 square miles of local inflows up the Marsh River to Shelly, Goose River to Hillsboro, and the Sandhill River to Climax. The Thompson to Grand Forks reach primarily consisted of local Red River drainage and inflows downstream of the Red Lake River gage at Fisher, MN (530 total square miles). Eight river systems contribute to the Red River between Grand Forks and Drayton. As described in Section B4.2 of this report, they include Cole Creek, the Turtle, Forest and Park Rivers on the North Dakota side of the Red River and the Grand Marais, Middle, Snake and Tamarac Rivers on the Minnesota side of the Red River.

B4.4 SYNTHETIC DESIGN EVENT HYDROGRAPHS

Four synthetic event evaluations were used for design and alternative analysis. The 10-, 2-, 1- and 0.2-percent chance flood events were analyzed with the unsteady HEC-RAS model. The modeling methodology for the synthetic events is identical to that of the historic events except that instead of matching an observed stage and discharge at a gage, the synthetic hydrographs are modeled to match balanced hydrographs. The balanced hydrographs were created by the Corps of Engineers at the USGS gage locations on the Red River including Hickson, ND, Fargo, ND, Halstad, MN, Thompson, ND, Grand

Forks, ND, and at the downstream end of the model near Drayton, ND. See Appendix A - Hydrology for additional balanced hydrograph background.

Balanced hydrographs were used as inflow hydrographs throughout the entire Red River model in the Phase 3 study. The balanced hydrograph shape and coincident hydrograph determination introduced an increased level of uncertainty as the model became larger and more detail was added. Between Fargo and Halstad, three major river systems required coincident hydrograph determinations; the Sheyenne River, the Maple River, and the Buffalo River. The balanced hydrographs at Fargo and Halstad were developed and the intermediate locations had to be determined based on drainage area. The Sheyenne River has a very large drainage area with the upper portion of it regulated by Baldhill Dam. Many factors added complexity to the Sheyenne and Maple River systems leaving little basis for determining accurate coincident balanced hydrographs. A sensitivity analysis was conducted prior to the Phase 4 study that provided insight on the effects of modifying inflow hydrographs from the three rivers in question. The sensitivity analysis showed a moderate level of response to hydrograph adjustments and the resulting impacts with the project. The details of the sensitivity analysis are presented in Exhibit F.

After additional evaluation of the most appropriate hydrologic methods and consultation with the Hydrologic Engineering Center, it was agreed that the Phase 4 study hydrology would involve using a pattern hydrograph from a historic event as a basis for simulating tributary inflows. Inflows at the upper end of the model on the Red River originated from a balanced hydrograph at Hickson, ND. The format used for the historic event hydrograph development at Hickson was also used for the balanced hydrographs. The iterative procedure included inserting a modified version of the Hickson balanced hydrograph at the upper end of the Red River at cross section 2764835. The modified hydrograph routed to Hickson (XS 2563754) would match the actual balanced hydrograph as provided in Appendix A – Hydrology.

All tributary inflow hydrographs were developed using the 2006 event hydrograph as a baseline pattern. A ratio was applied to the 2006 hydrographs so the model matched the targeted balanced hydrographs as provided in Appendix A – Hydrology and as shown in Exhibit E of this report. The ratios were typically determined so the runoff volume between the gage locations and the local inflow hydrographs were relatively the same. Table B4 shows the typical tributary multipliers. The ratios varied slightly depending on the volume of water required to match the next downstream balanced hydrograph. The actual ratios used at each gage location for the four design events are shown on Figures B33, B34, B35, and B36 for the 10-, 2-, 1- and 0.2-percent chance events respectively. The local inflow hydrographs for the synthetic events were created in the same manner as they were for the historic events as outlined in Section B4.3 on ungaged inflow hydrographs.

Table B5 – Typical 2006 Gage Multiplier for Synthetic Events

Event	Multiplier*
10-Percent Chance	0.65
2-Percent Chance	1.4
1-Percent Chance	1.8
0.2-Percent Chance	2.3

*values varied slightly by tributary.

As calibration and inflow hydrograph development progressed, it became apparent that the tributary peak timing relative to the Red River played an important role in determining the final size and shape of the Red River hydrographs. The timing of the eight largest historic floods was analyzed to determine the date at which each tributary peaks with respect to the peak on the Red River at adjacent stream gages. This provided support for determining the appropriate timing of the synthetic event tributary hydrographs.

Balanced Hydrographs provided by USACE include:

- Red River of the North - USGS Gage 05051522 at Hickson, ND
- Red River of the North - USGS Gage 05054000 at Fargo, ND
- Red River of the North - USGS Gage 05064500 at Halstad, MN
- Red River of the North - USGS Gage 05070000 at Thompson, ND
- Red River of the North - USGS Gage 05082500 at Grand Forks, ND
- Red River of the North - USGS Gage 05092000 at Drayton, ND

B5.0 MODEL CALIBRATION AND VERIFICATION

The 2009 spring flood event was chosen for model calibration because it is the current flood of record and was well documented by high water marks and stream gage data. The 2006 spring flood was the fifth highest flood on record through the Fargo/Moorhead area and was chosen as the pattern event for the balanced hydrographs. Notice the order of which the verification events have been presented, 2006, 1997, and 2010. This is related to the validity of the verification. The 2006 event had more documented gage records than the 1997 event. The 2010 event hadn't occurred during the Phase 2 study and the observed gage records were not available until late in the Phase 3 study. Much of the 2010 data was considered preliminary at that time so a lesser emphasis was placed on the data. The 2006 flood event was conveyed through the model as the primary verification event. Prior to the 2009 flood, the 1997 spring flood event was the highest flood event on the Red River. The 1997 spring flood was used as the second verification event. The third verification event came from the most recent flood in 2010. The flood of 2010 was recently documented as the sixth highest flood through Fargo/Moorhead and the first time the area has experienced back-to-back years with floodwaters above major flood stage. Figures B37-B40 show the locations of high water marks from the 2009, 2006, 1997, and 2010 floods that were utilized for model calibration and verification.

B5.1 HISTORIC EVENT MODEL GEOMETRY CHANGES

Flood protection measures are typically constructed by communities up and down the Red River. The Cities of Fargo and Moorhead, along with rural Cass and Clay Counties utilize both permanent and emergency flood protection measures. Permanent flood protection includes earthen levees and floodwalls, while emergency measures consist primarily of clay and sandbag levees with a few locations protected with various manufactured products. Regardless of the protection method, the riverine characteristics are relatively the same for modeling purposes. For model calibration and verification, levees were added to the model geometry to simulate flood protection measures. Figure B19 highlights the typical lines of permanent and emergency flood protection measures used during the 2009 flood.

Substantial development has expanded Fargo and Moorhead to the south since the 1997 flood. With the additional development, the Cities have continued to make efforts to provide protection from the Red River and the Wild Rice River. In 1997, the Fargo line of protection paralleled Rose Coulee and Drain 53 east of Interstate 29and south of Interstate 94, and was made up of localized protection west of Interstate 29. Nine years later, in 2006, and then again in 2009, the line of protection was extended approximately 7 miles south to Cass County Road 16. There were two other minor differences between 2006 and 2009 protection limits. As described above, the 2009 event was larger than 2006 requiring a dike to be created along 25th Street between 88th Avenue S. and 100th Avenue S. In addition, overtopping of a half mile length of County Road 16 was prevented in 2009 (just west of Interstate 29). 2010 had similar protection limits to 2009. The geometry for both the historic and synthetic event models included the typical temporary and permanent flood protection measures of cities up and down the Red River including the cities of Grand Forks and East Grand Forks.

B5.2 2009 FLOOD CALIBRATION

The 2009 spring flood was anticipated early in the fall of 2008 when the basin experienced one of the wettest falls on record saturating the landscape leading into freeze up. This was followed by above average snowfall through the winter. The melt began with extreme rainfall throughout the southern part of the Red River Basin that led to a rapid snow melt. The magnitude of the flood intensified when more than 2 inches of rain fell just a few days prior to the crest followed by temperatures falling into the single digits. The National Weather Service crest projections increased several times in the days leading up to the crest. The communities of Fargo and Moorhead narrowly escaped devastation with a successful flood fight. The 2009 flood carried along many unique characteristics of which only some were able to be modeled.

During the calibration, the hydrographs at Abercrombie and Hickson were routed downstream to the Fargo gage. As described in Section B4.2 of this report, local inflows were proportionally added to the system. The required local inflow hydrograph was compared to day-to-day snow water equivalent charts throughout the basin. Early in the calibration, an attempt was made to account for uneven rainfall distribution across the ungaged drainage areas. The result of this was very limited and for calibration purposes, a uniformly distributed hydrograph was used.

Two additional stream gages (HOBO) were placed on the Wild Rice River for the 2009 event. The stream gages provided stage data for comparison. The field flow measurements for the stream gages were only obtained on the receding limb of the hydrograph resulting in a skewed calculated discharge hydrograph that was of limited value.

Eight additional stage gages (HOBO) were placed along the Red River between the Wild Rice River, ND and Georgetown, MN. Although these gages did not provide discharge records, the stage measurements were very beneficial in calibrating the model to match stage throughout the flood.

As noted in the geometry section, geometry parameters such as ineffective flows, overbank reach lengths and manning's n values were adjusted to calibrate not only the peak, but the entire stage and flow hydrograph throughout the Red River. Several sensitivity modifications were made to the geometry to identify the resulting impact and response of the model. At no point did the discharge hydrograph ever match perfectly at the Fargo gage. This is attributed to the rainfall and extreme temperatures leading up to the crest. It was very difficult to obtain the maximum stages corresponding to the observed discharge. Manning's "n" values were set at reasonable values, yet were on the upper end of the accepted range of values. After looking at the calibration in detail, it is anticipated that a vertical variation in "n" value may be beneficial since much of the overbank conveyance is through heavy tree cover. As the stages increase, a larger percentage of the conveyance is through the tree canopy with more restriction. This would be modeled with lower "n" values at lower discharges and increasing "n" values with stage. This level of detail would likely not be feasible in a project as large and complex as this one.

Other uncertainties identified while calibrating the model to the Fargo gage as well as downstream gages involves the quality of the available observed USGS stream gage data. If the discharge data is off by 5% (good), 8% (fair), or greater than 8% (poor), it could easily affect the comparison to the known stage data and surveyed high water marks. It would then show that the model is not accurately calibrated when the real issue is related to the amount of water added to the system. The Hickson stream gage data for 2009 was rated "poor" at the crest and "fair" half way down the receding limb. The Abercrombie stream gage measurements for 2009 were rated "fair" near the crest. This means that each of the upstream gage discharges could be eight percent or greater from the measured values. The Fargo stream gage measurements through the crest were rated "good" meaning the actual discharges could be up to 5 percent from the measured discharges. With discharge measurements of approximately 29,400 cfs near the crest at Fargo, the actual discharge could range from 27,900 cfs to 30,900 cfs. Based on the rating curve at the Fargo gage, this could affect stage by approximately 0.4 feet. The modeled hydrograph compared to the observed hydrograph and quality measurements is shown in Exhibit A for 2009.

The Halstad gage had many issues with discharge measurements during the 2009 flood. It had several field measurements with poor ratings. Discussions with local USGS representatives concurred with the ratings and suggested that the 2009 discharge data at Halstad not be used and more emphasis be placed on the discharge data at the Thompson gage instead. Exhibit A for the Halstad gage reflects the discrepancies between modeled and measured discharges for 2009. Stage data at Halstad did not have issues.

Another difficult characteristic to model is that the cold temperatures during the flood caused lower velocity surface waters to freeze. Although the ice layer wasn't very thick and did not cause ice jams, it may have however created additional surface roughness resulting in stage increases.

Peak stage calibration was relatively easy to achieve in areas other than directly upstream of Fargo/Moorhead near the Wild Rice River, ND confluence, downstream of Fargo/Moorhead through the Oakport Township area and through the encroached floodplain of the Fargo/Moorhead area. The known discrepancies can be attributed to any of the above noted issues.

B5.3 2006 FLOOD VERIFICATION

The 2006 flood crest at the Fargo gage occurred on March 28th. Temperatures were very mild resulting in a uniform runoff. No rainfall or blizzards caused adverse impacts to consider during verification. Much less observed data was available for the 2006 event than the 2009 event. The USGS gages as well as high water elevation marks throughout the Red River with a higher density through the Fargo/Moorhead area, was all that was available

Gage quality data was extremely critical at Hickson, Abercrombie, and at the Fargo gage during the 2006 event. Since the temperatures were relatively warm, local runoff contributed to the river system well before the main crest. Routing the Hickson and Abercrombie hydrographs to the Fargo gage created a hydrograph that was already larger than the gaged data. The discharge measurements were rated "fair" near the peak (19,200 cfs 4/4/2006), so the actual discharges could be up to eight percent from actual (17,700 cfs to 20,700 cfs). With minor local inflow contributions, the modeled discharge hydrograph and resulting stage data provided a reasonable match to high water marks. Here it was assumed that the measured USGS discharge at the Fargo gage was underestimated because the other historic events matched stage and discharge and the discharge in the 2006 model provided a reasonable stage calibration. See Exhibit B for 2006 modeled hydrograph and USGS measured hydrograph comparisons along with the field measurement quality ratings.

B5.4 1997 FLOOD VERIFICATION

Prior to the 2009 flood, the 1997 flood event was the highest on record at the Fargo gage. The 1997 flood was very unique with a freeze thaw cycle that caused bi-modal (dual peak) discharge hydrographs at many locations. The specific timing of the flood peaks often created very wide hydrographs with significant volume. One challenge when developing the 1997 verification was the limited gage data and high water elevation records. The Thompson gage between Halstad, MN and Grand Forks, ND was not yet established in 1997. Hickson, Fargo and Halstad did not have stage hydrographs available. Another notable issue was that the Grand Forks levees overtopped and breached leading up to the crest. Rough estimates of conveyance through the city were computed during post flood evaluations. However, for this project, the permanent protection through Grand Forks, ND and East Grand Forks, MN were assumed to be in place for the 1997 flood verification. Comparison hydrographs, where available for 1997, are shown in Exhibit C.

B5.5 2010 VERIFICATION

The 2010 flood event was originally projected to be as extreme as the flood in the previous year. As the flood crest drew nearer, the prediction narrowed in on elevations slightly less than that of 2009. The 2010 flood came very fast and the crest occurred on March 21st. The largest challenge for the model verification using the 2010 flood event was that at the time of the model development, data was not available yet. Provisional data was supplied by the USGS; however the data has not been completely replaced with approved data. Additional information has recently become available and will be incorporated into the verification in the future. Hydrograph comparisons between the model results and observed data is shown in Exhibit D for 2010.

B6.0 MODEL PEER REVIEW AND QA/QC MEASURES

Due to the complexity of the unsteady HEC-RAS model and the greater role it is playing in the project design for the Phase 4 study, a formalized peer review process was initiated by the Project Team. This effort was led by Stu Dobberpuhl at Moore Engineering and included internal peer review of both the existing conditions and with-project models. Peer review for the existing conditions unsteady model was performed by experts from Moore Engineering, Inc., Barr Engineering, and HDR. The results of the peer review along with responses to the review comments are contained in Exhibit H of this report. Additionally, the peer review resulted in the identification of future modeling needs that area summarized in Appendix C Hydraulics with project conditions.

B7.0 EXISTING CONDITION MODEL RESULTS

B7.1 HISTORIC EVENT RESULTS

In summary, four historic flooding events were evaluated with the unsteady state HEC-RAS model. The 2009 event was used for calibration. The 2006, 1997 and 2010 events were used to verify the calibrated model. Although the historic events were not intended for design, they provided a good sense of assurance that the model was reasonably calibrated and not uniquely connected to one event with abnormal conditions. Existing Conditions Model results along with inundation maps pertaining to specific events are presented with the impact tables and impact maps in Appendix C – Hydraulics Design.

B7.2 SYNTHETIC EVENT RESULTS

After the model was calibrated and verified with the historic events, four synthetic events were developed for use in design and impact analysis. As with the historic events, model results and flood inundation maps are displayed in Appendix C Hydraulics with project conditions.

B8.0 REFERENCES

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4. Houston Engineering, Inc., City of Fargo Southside Flood Control Project Unsteady Hydraulic Modeling, Draft – December, 2007.

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7. Houston Engineering, Inc., Buffalo River Flood Insurance Study, August, 2006.

8. International Water Institute, Red River Basin LiDAR Mapping Initiative, Blocks A, B, C and D, spring 2008.

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12. Horizons, Inc., Wild Rice River, MN LiDAR Collect, spring 2002.

13. U.S. Department of Agriculture Soil Conservation Service, Floodplain Management Study, Wild Rice River, Cass and Richland Counties, North Dakota, Undated.

14. Houston Engineering, Inc., Technical Support Data Notebook for Stanley and Pleasant Townships, Cass County, ND and Holy Cross and Kurtz Townships, Clay County, MN Flood Insurance Study, January 5, 2006.

15. Federal Emergency Management Agency, Flood Insurance Study, City of Harwood, North Dakota, Cass County, September 4, 2002.

16. Federal Emergency Management Agency, Flood Insurance Study, Township of Reed, North Dakota, Cass County, September 4, 2002.

17. U.S. Army Corps of Engineers, HEC-RAS 4.1 Modeling Software, January, 2010.

18. U.S. Army Corps of Engineers, St. Paul District, Flood Reduction Studies for East Grand Forks, Minnesota and Grand Forks, North Dakota, Sub-Appendix A2: Hydraulic Analysis, 1998.

19. Federal Emergency Management Agency, Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix C: Guidance for Riverine Flooding Analysis and Mapping, November, 2009.

Appendix B – Hydraulics
Existing Condition

Figures

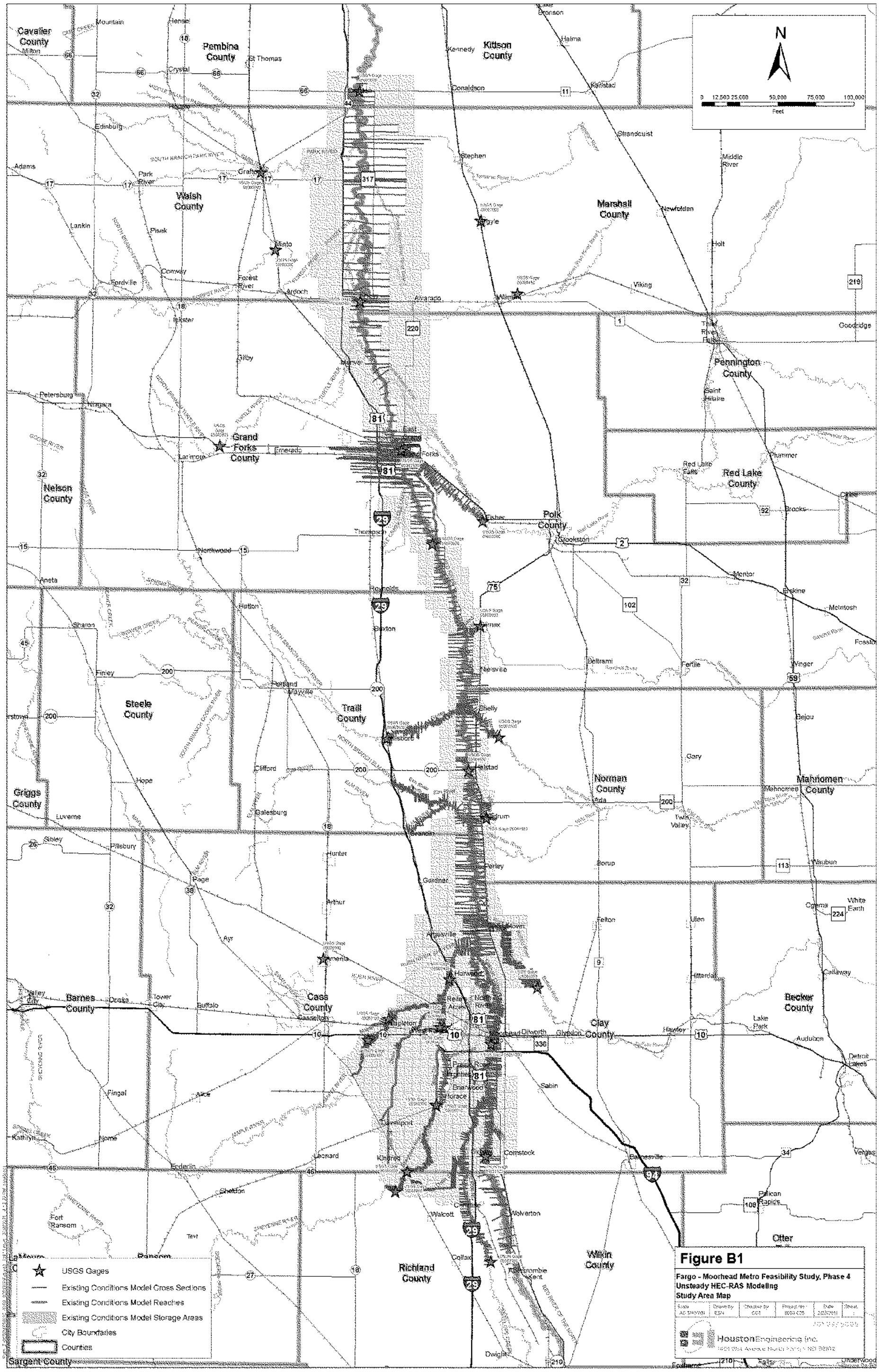


Figure B1
Fargo - Moorhead Metro Feasibility Study, Phase 4
Unsteady HEC-RAS Modeling
Study Area Map
USGS Gages
Existing Conditions Model Cross Sections
Existing Conditions Model Reaches
Existing Conditions Model Storage Areas
City Boundaries
Counties
Houston Engineering Inc.
Cavalier County
Pembina County
Kittson County
Walsh County
Marshall County
Pennington County
Grand Forks County
Nelson County
Red Lake County
Polk County
Steele County
Traill County
Norman County
Mahnomen County
Griggs County
Barnes County
Cass County
Clay County
Becker County
Richland County
Wilkin County
Otter Tail County
Ransom County
Sargent County

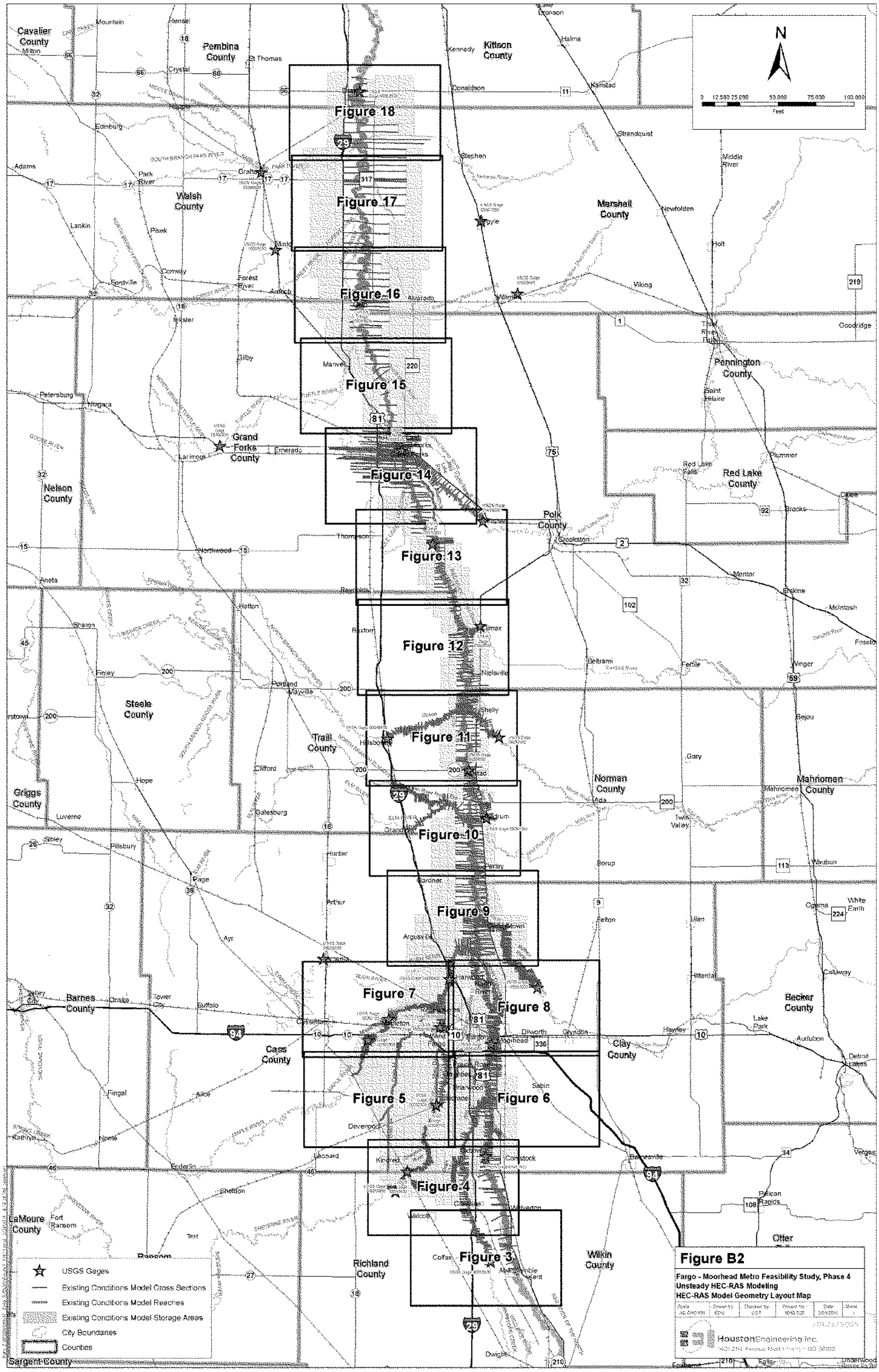
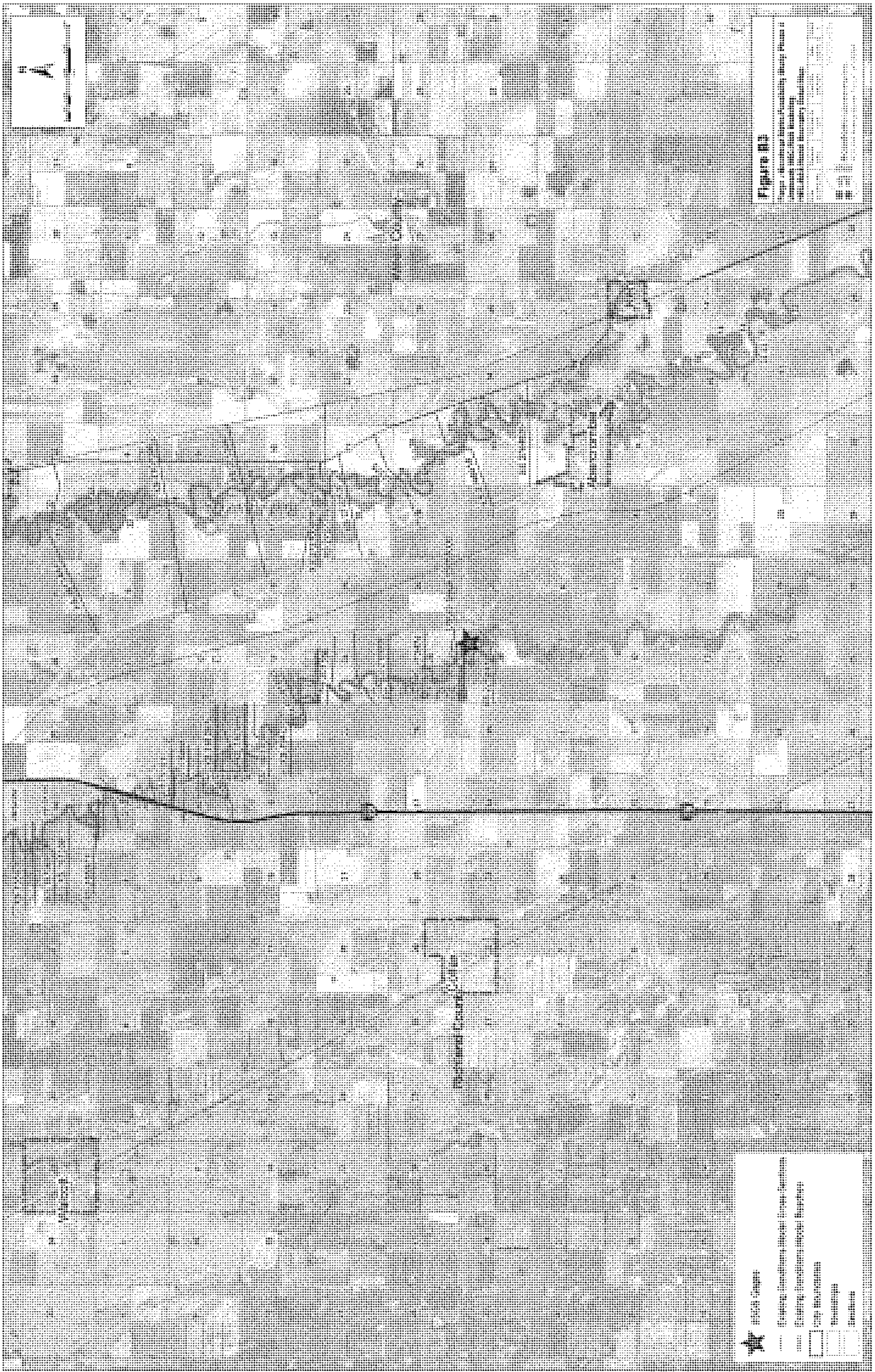
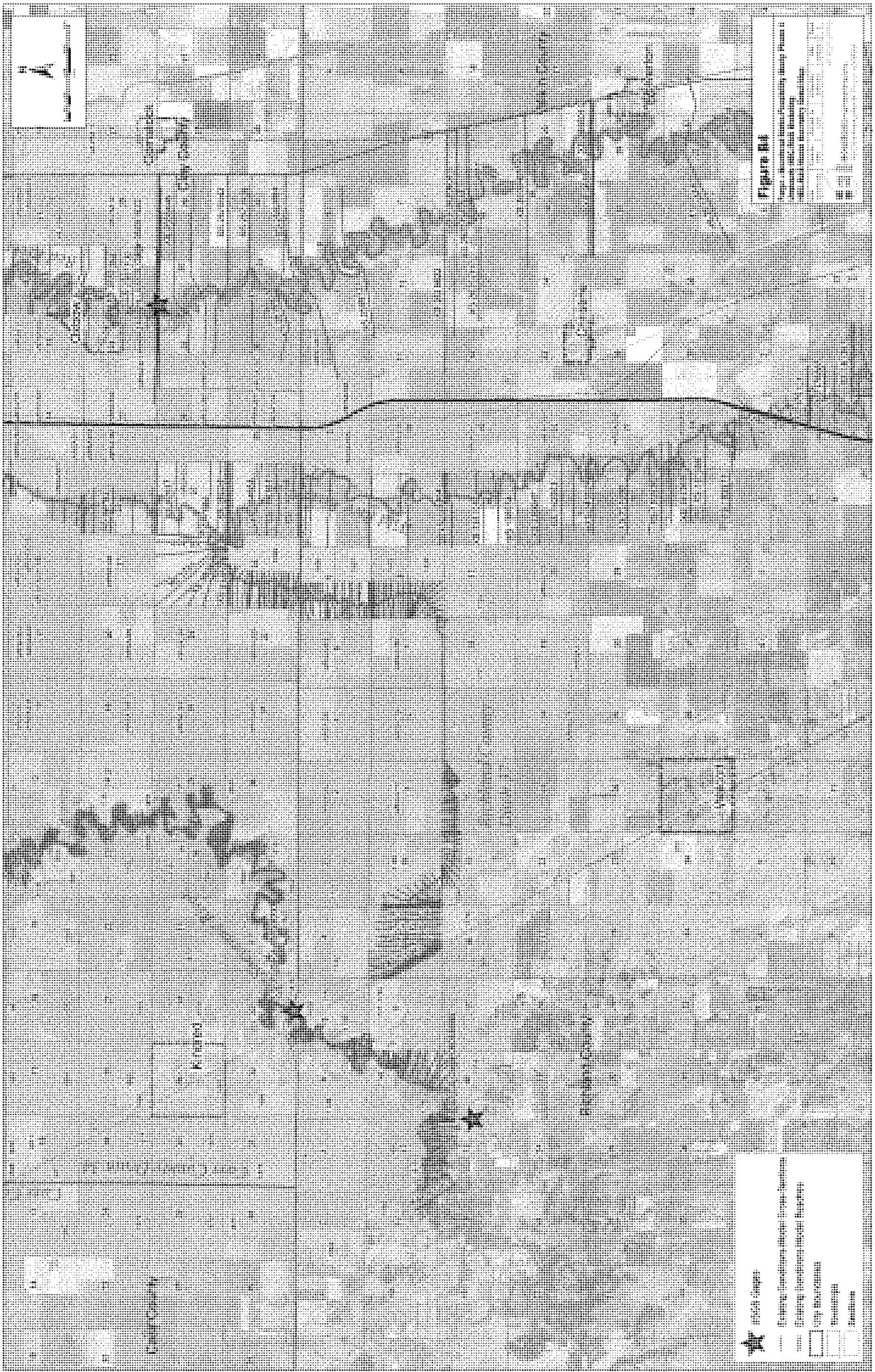
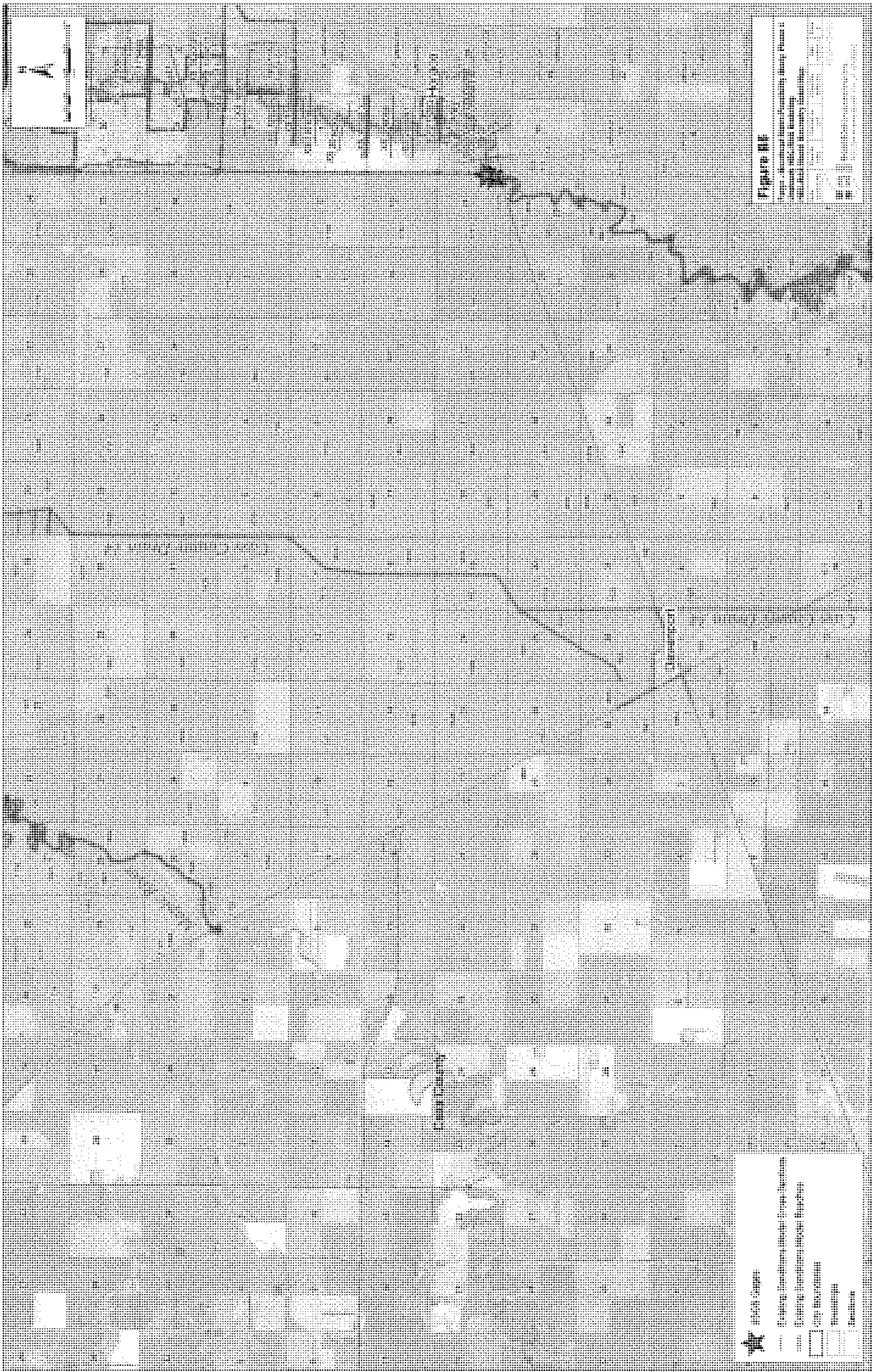
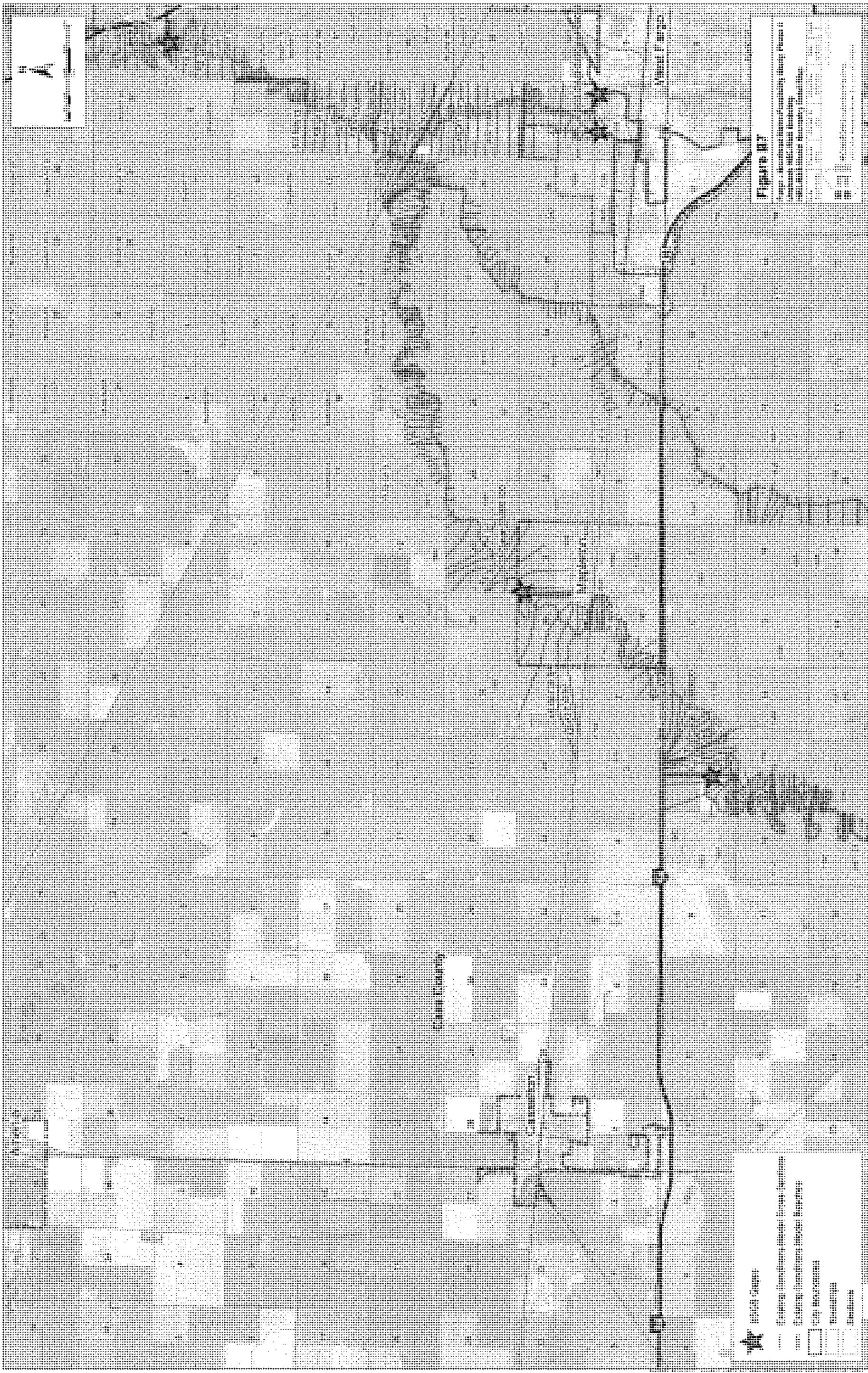


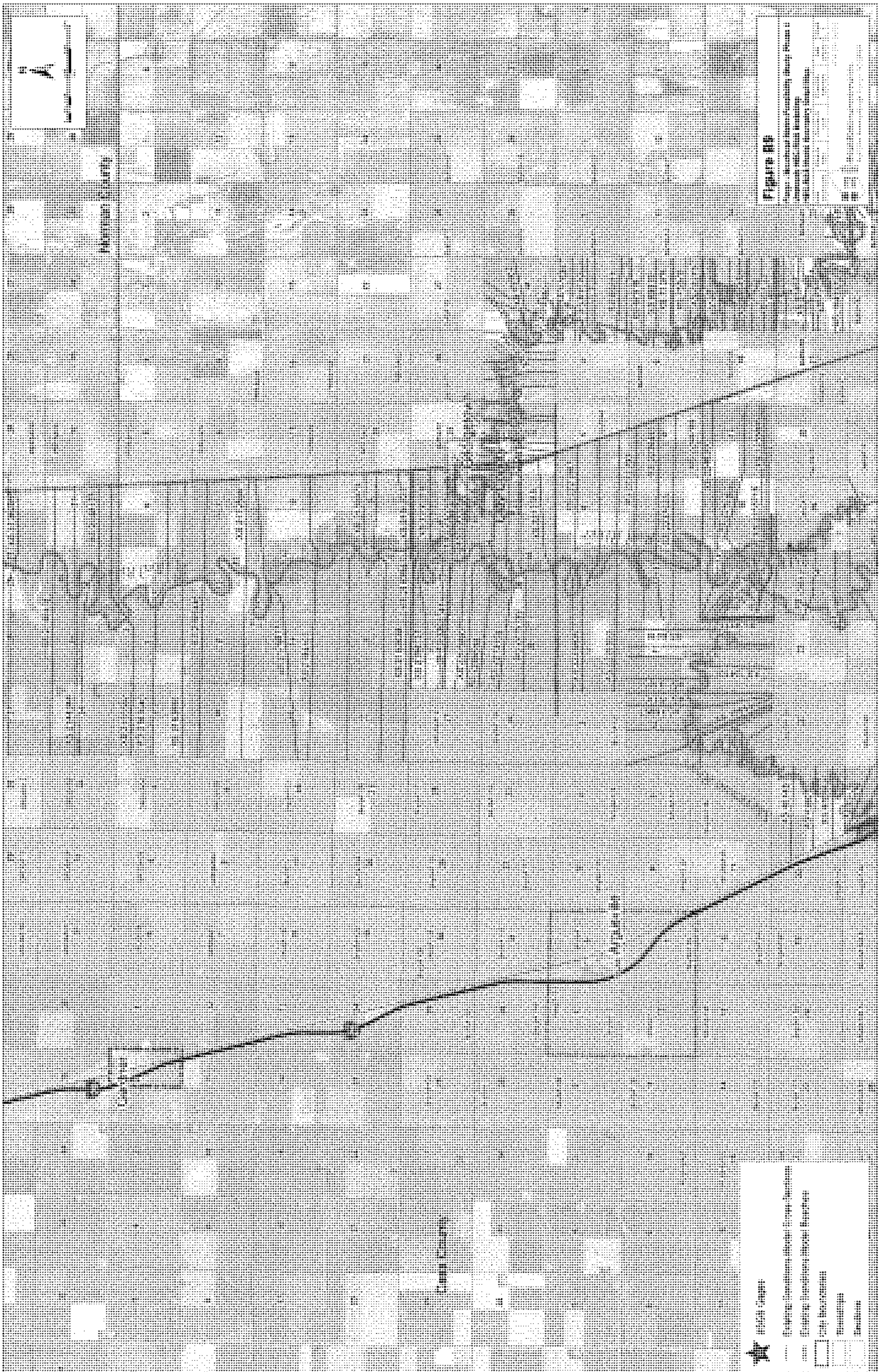
Figure 18
Figure 17
Figure 16
Figure 15
Figure 14
Figure 13
Figure 12
Figure 11
Figure 10
Figure 9
Figure 7
Figure 8
Figure 5
Figure 6
Figure 4
Figure 3
Cavalier County
Pembina County
Kittson County
Walsh County
Marshall County
Pennington County
Grand Forks County
Nelson County
Red Lake County
Polk County
Steele County
Traill County
Norman County
Mahnomen County
Griggs County
Barnes County
Cass County
Clay County
Becker County
LaMoure County
Richland County
Wilkin County
Otter Tail
Sargent County
USGS Gages
Existing Conditions Model Cross Sections
Existing Conditions Model Reaches
Existing Conditions Model Storage Areas
City Boundaries
Counties
Figure B2
Fargo - Moorhead Metro Feasibility Study, Phase 4
Unsteady HEC-RAS Modeling
HEC-RAS Model Geometry Layout Map
HoustonEngineering Inc.
N

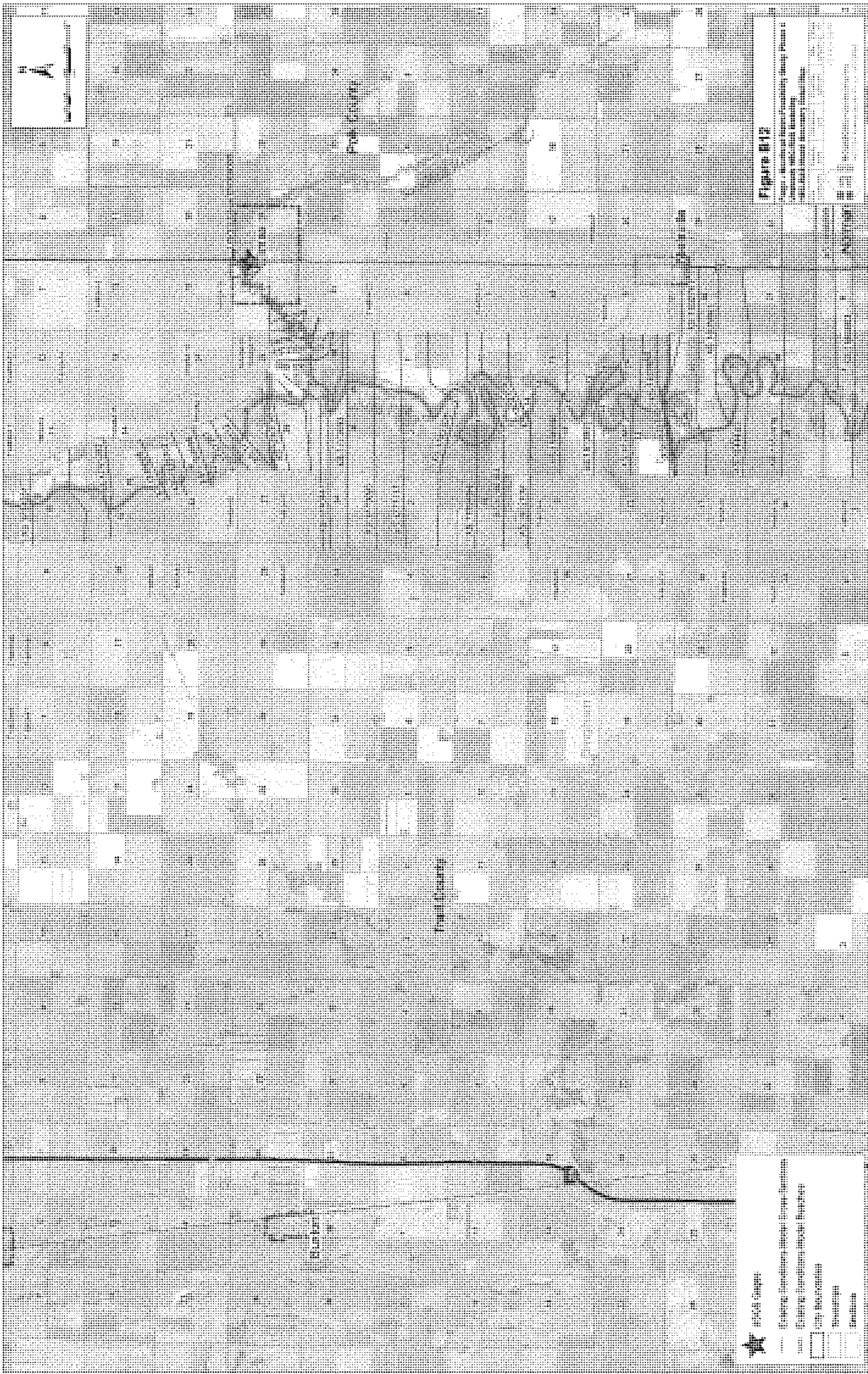


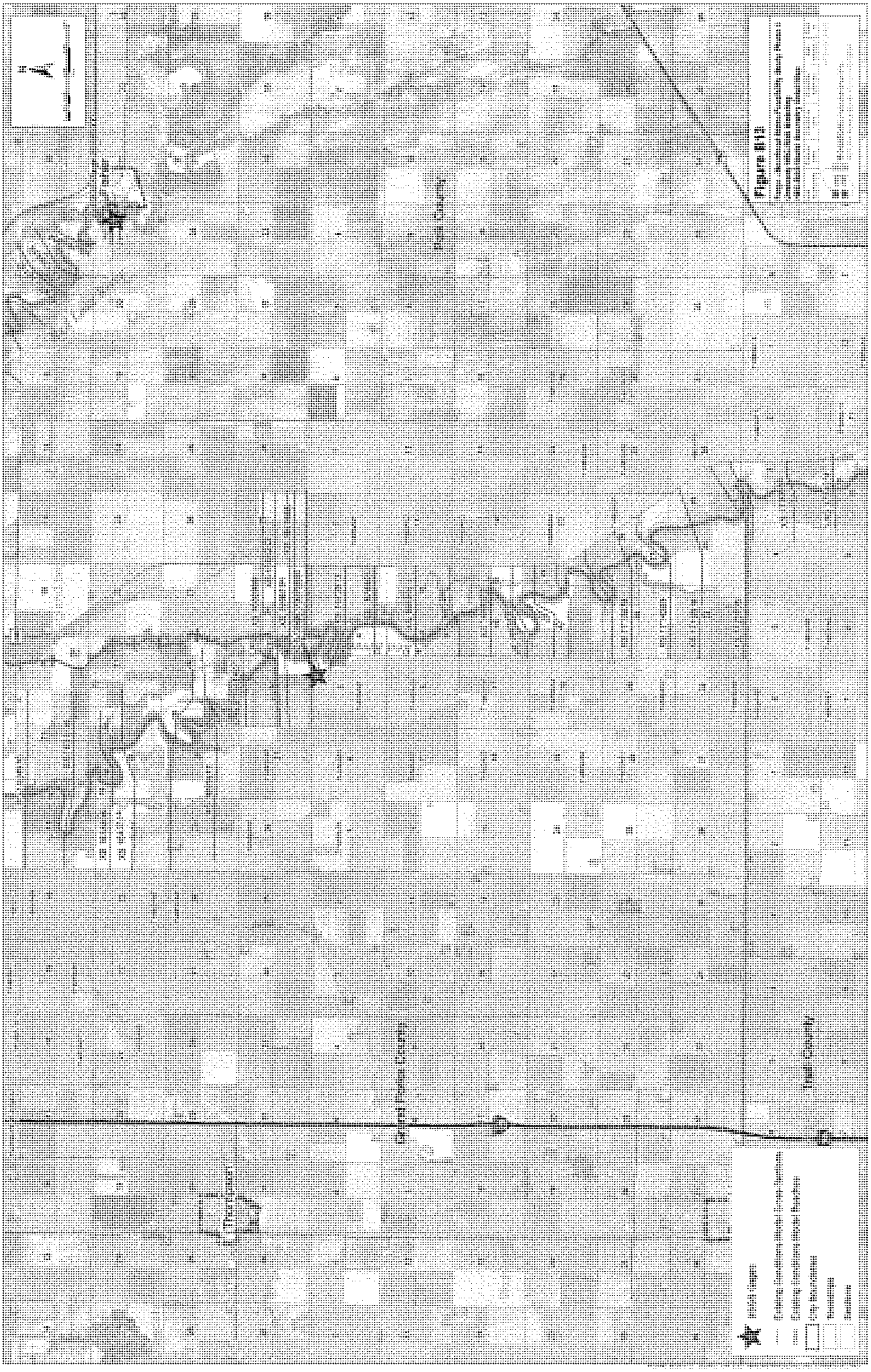


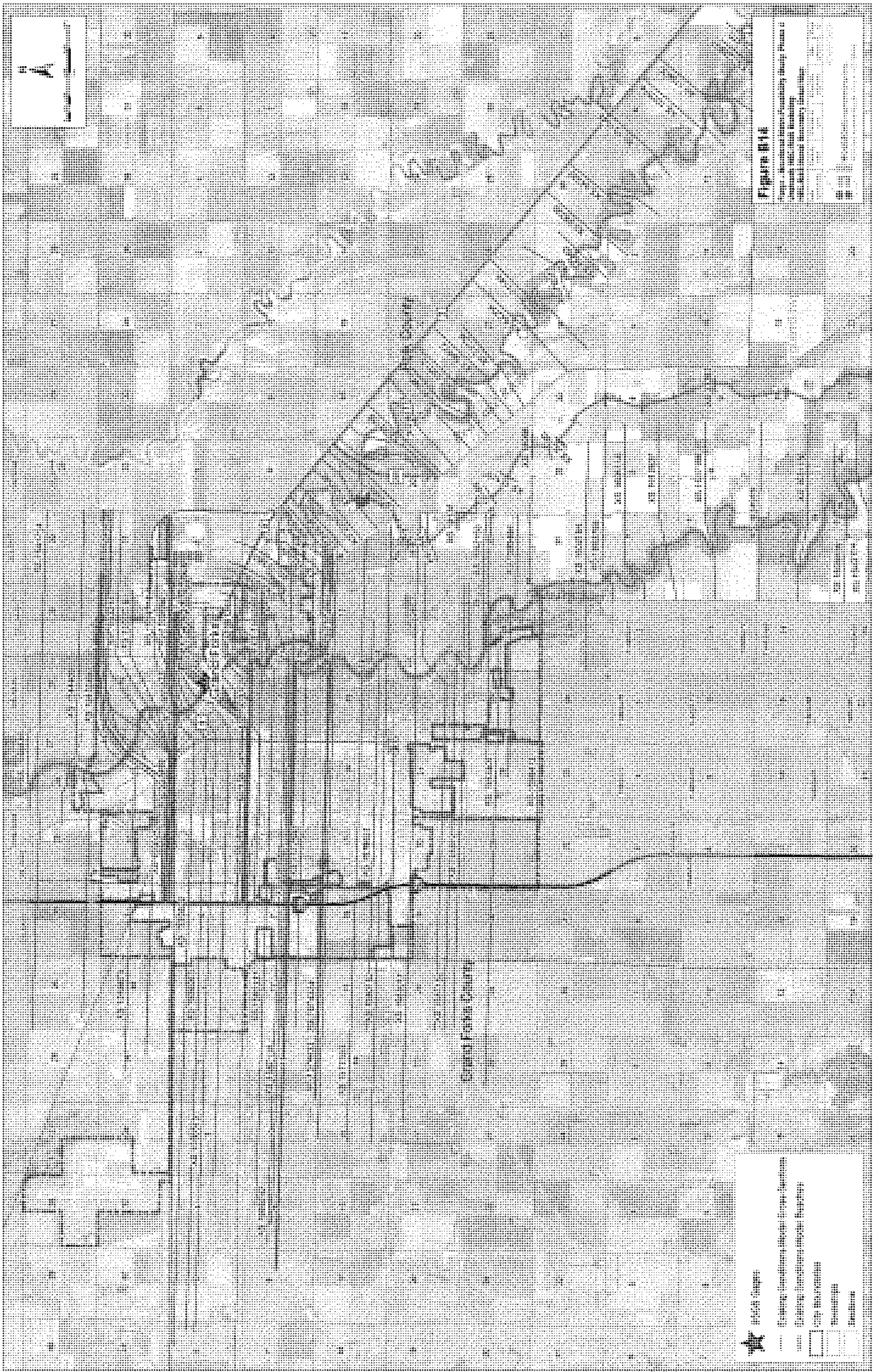


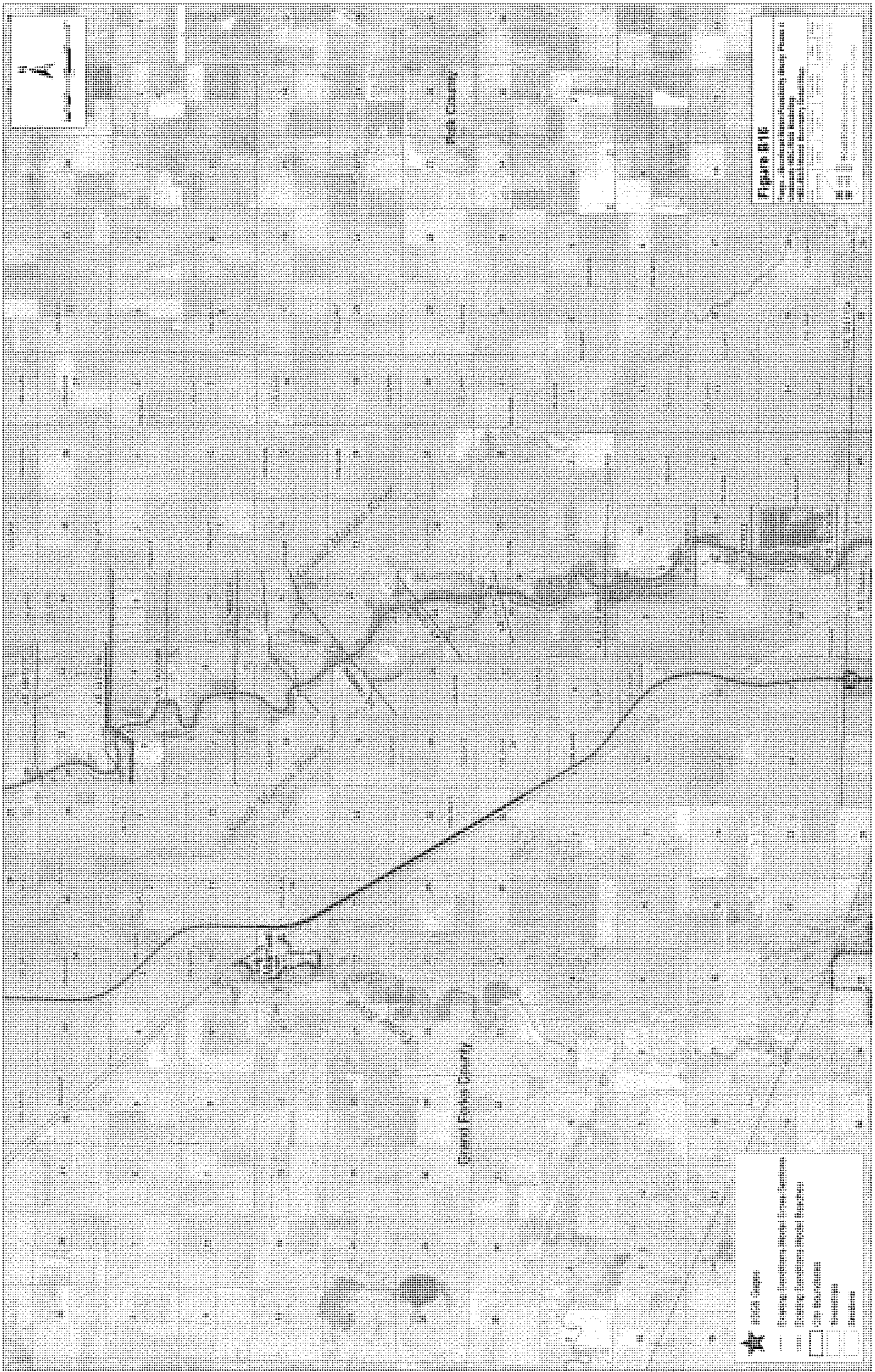


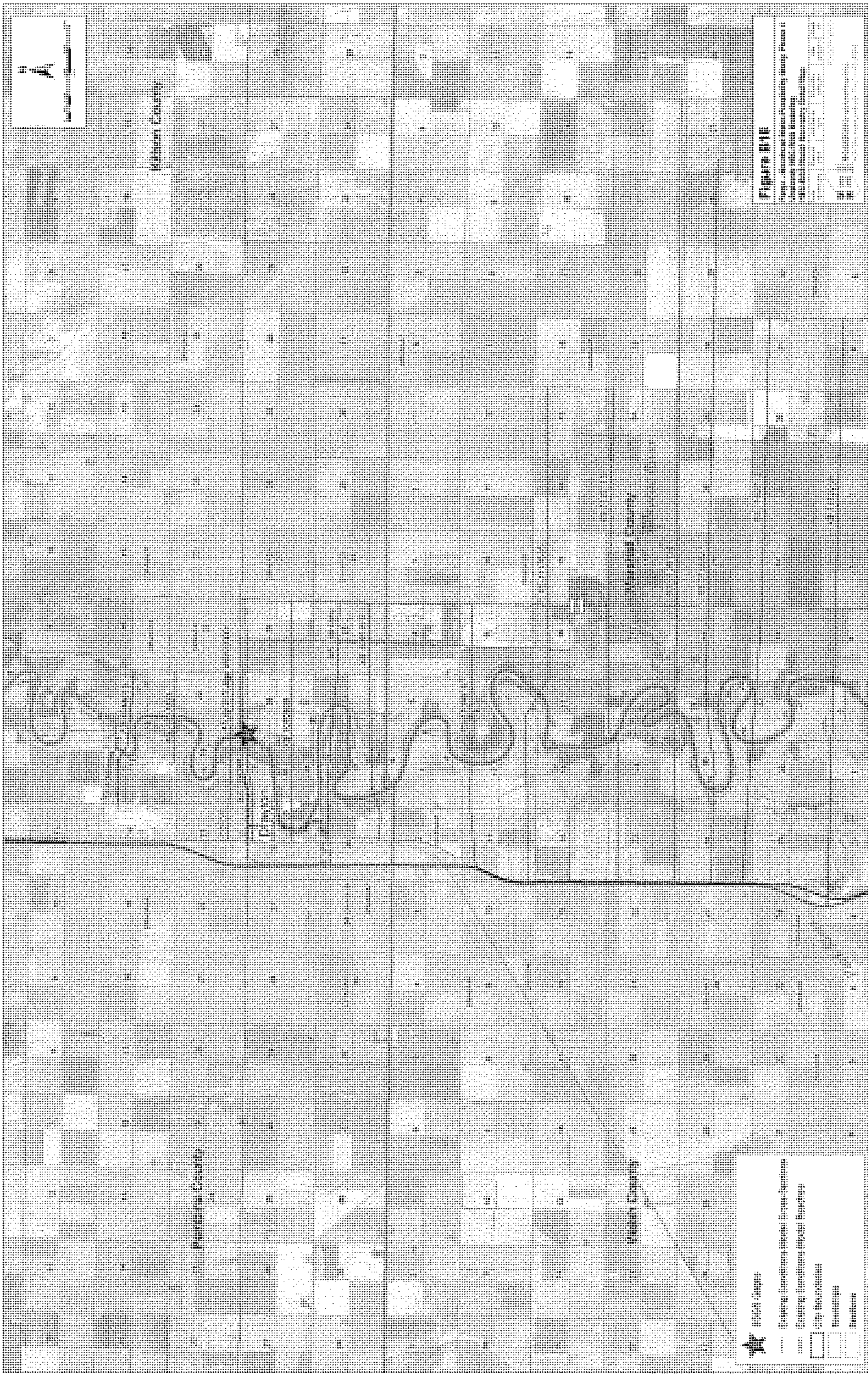


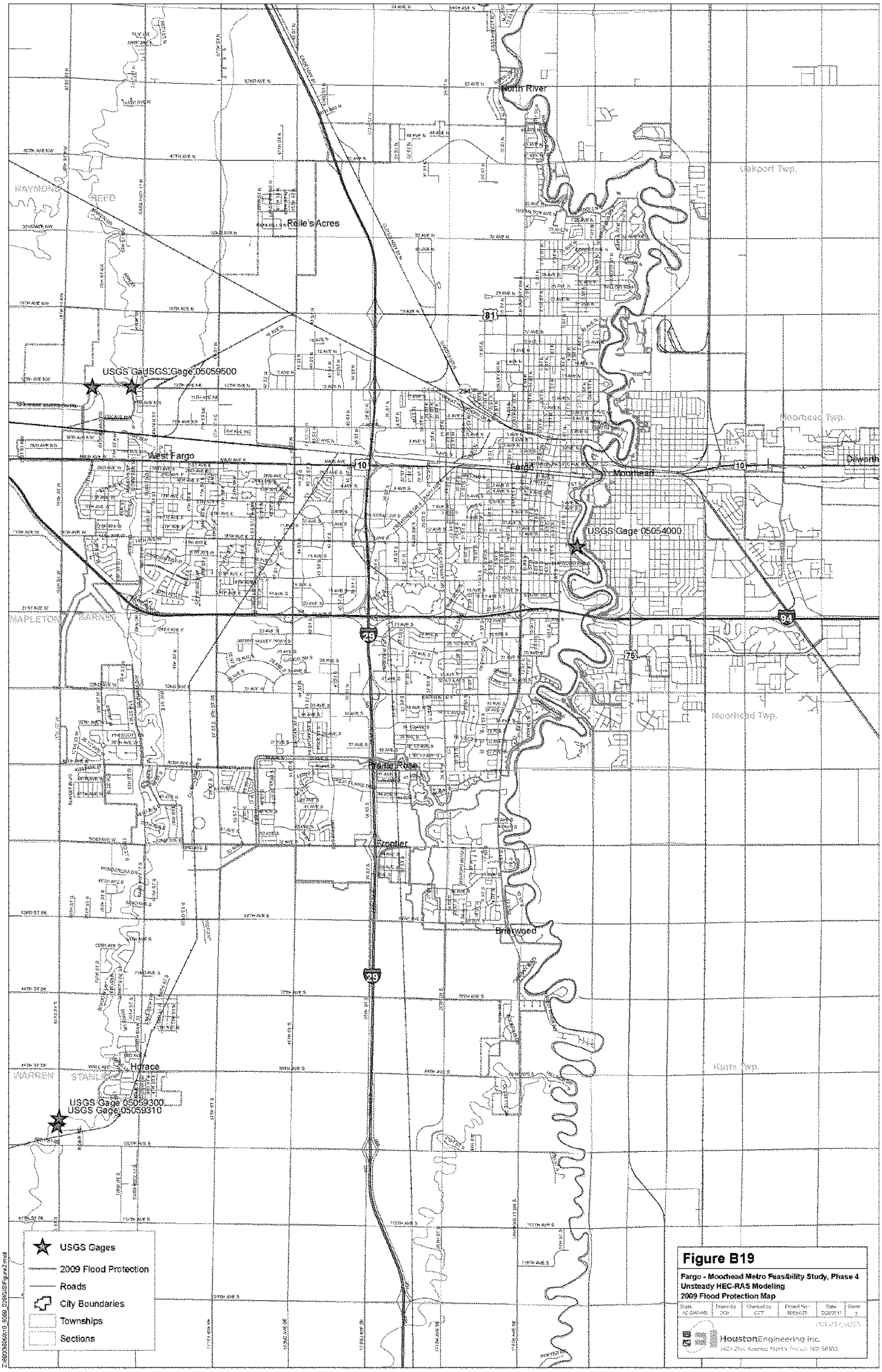











North River
Oakport Twp.
Reile's Acres
USGS Gage 05059500
West Fargo
Fargo
Moorhead
Moorhead Twp.
Dilworth
USGS Gage 05054000
MAPLETON
BARNES
Prairie Rose
Frontier
Briarwood
Horace
WARREN
USGS Gage 05059300
USGS Gage 05059310
Kurtz Twp.
USGS Gages
2009 Flood Protection
Roads
City Boundaries
Townships
Sections
Figure B19
Fargo - Moorhead Metro Feasibility Study, Phase 4
Unsteady HEC-RAS Modeling
2009 Flood Protection Map
Scale
Drawn by
Checked by
Project No.
Date
Sheet
HoustonEngineering Inc.

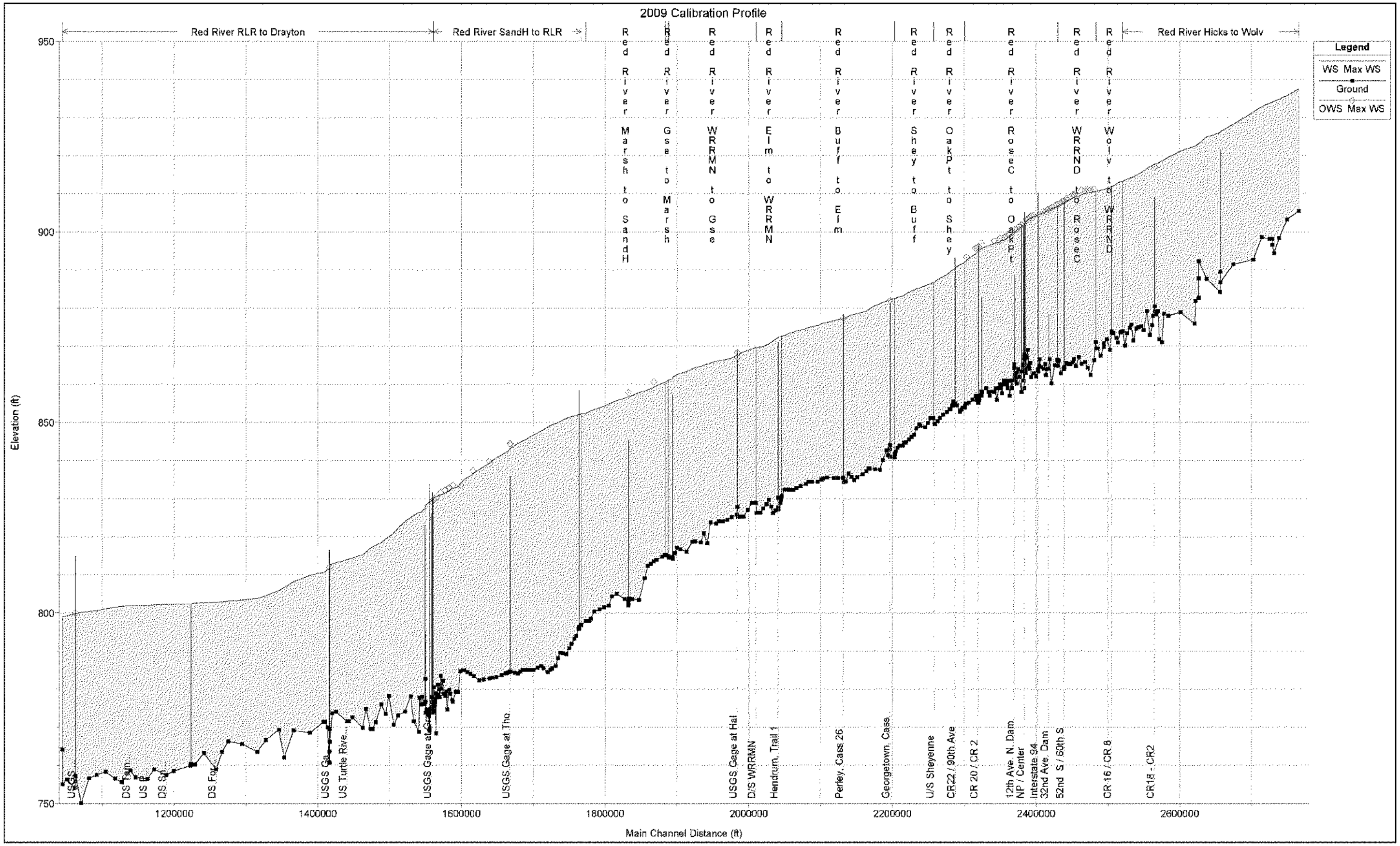


Figure B20 - 2009 Flood Calibration Profile for Red River of the North

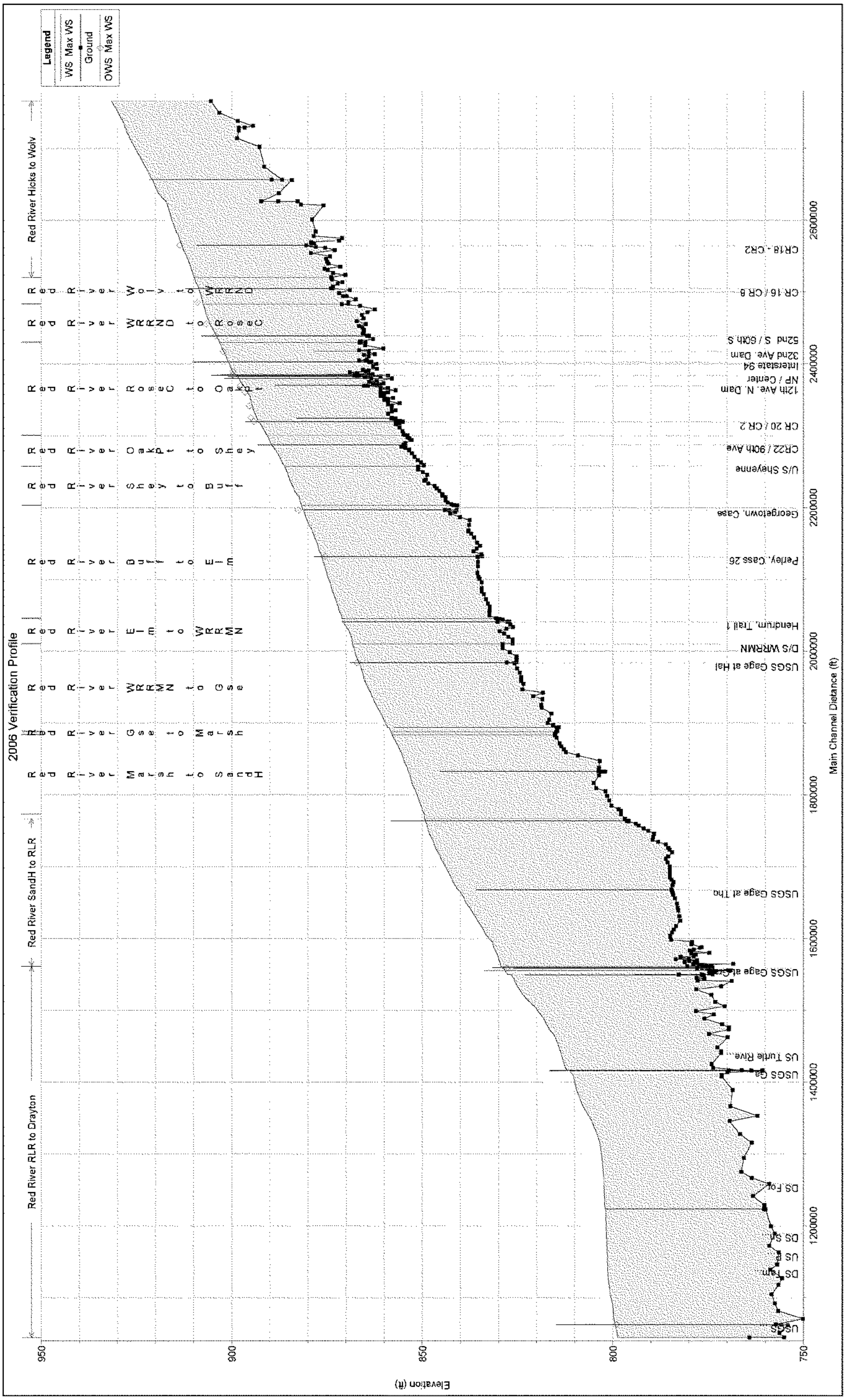


Figure B21 - 2006 Flood Verification Profile for Red River of the North

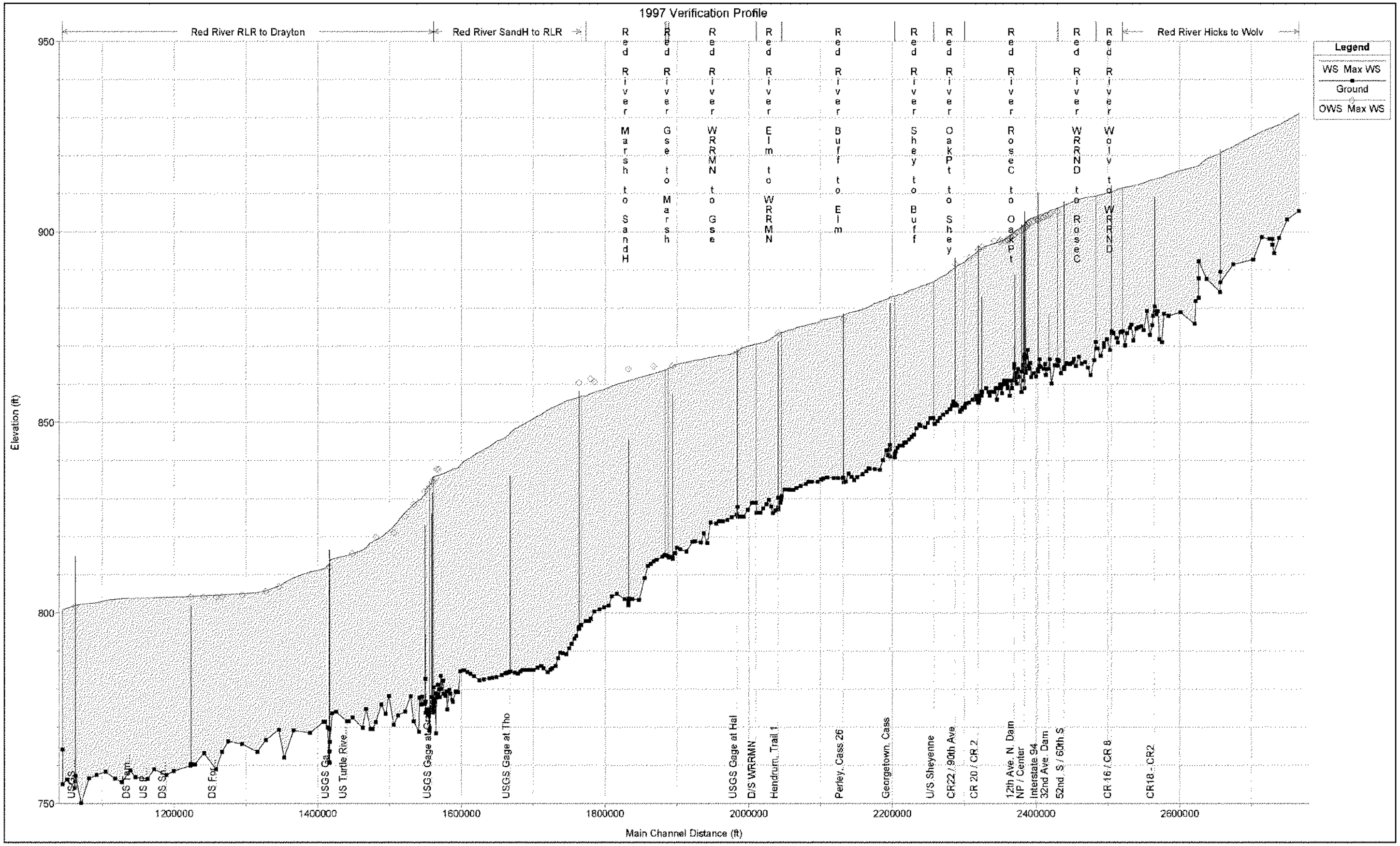


Figure B22 - 1997 Flood Verification Profile for Red River of the North

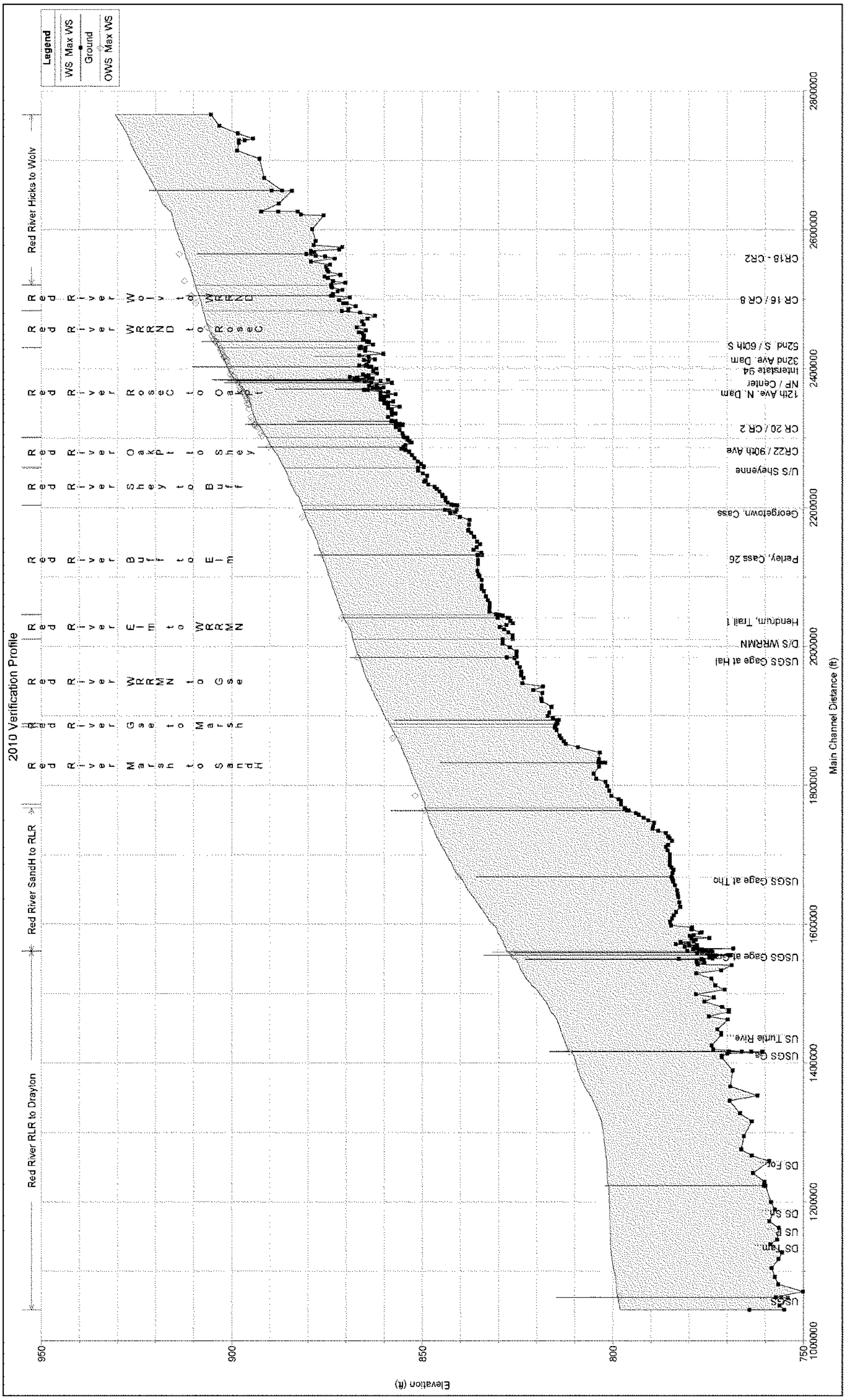


Figure B23 - 2010 Flood Verification Profile for Red River of the North

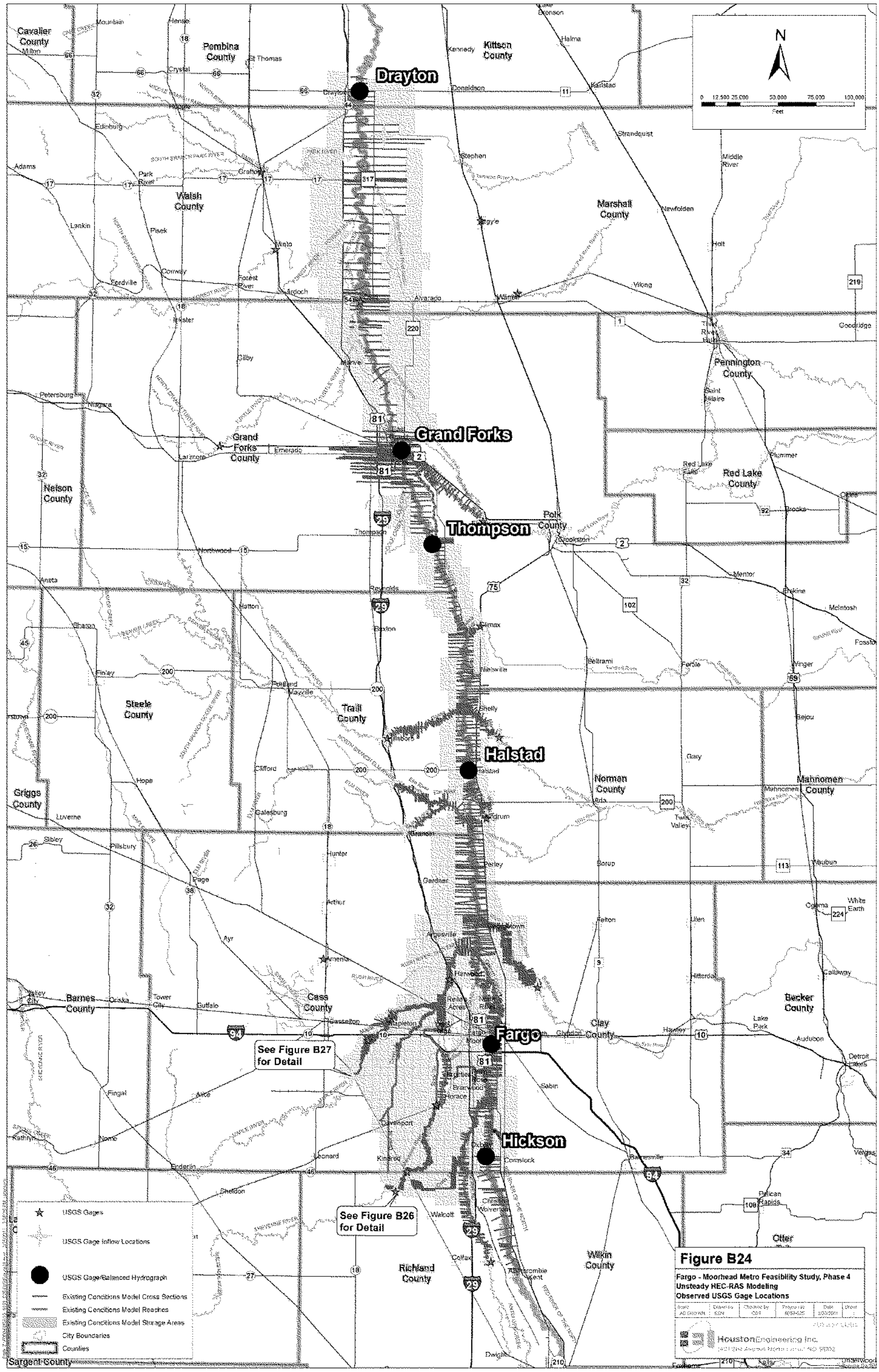
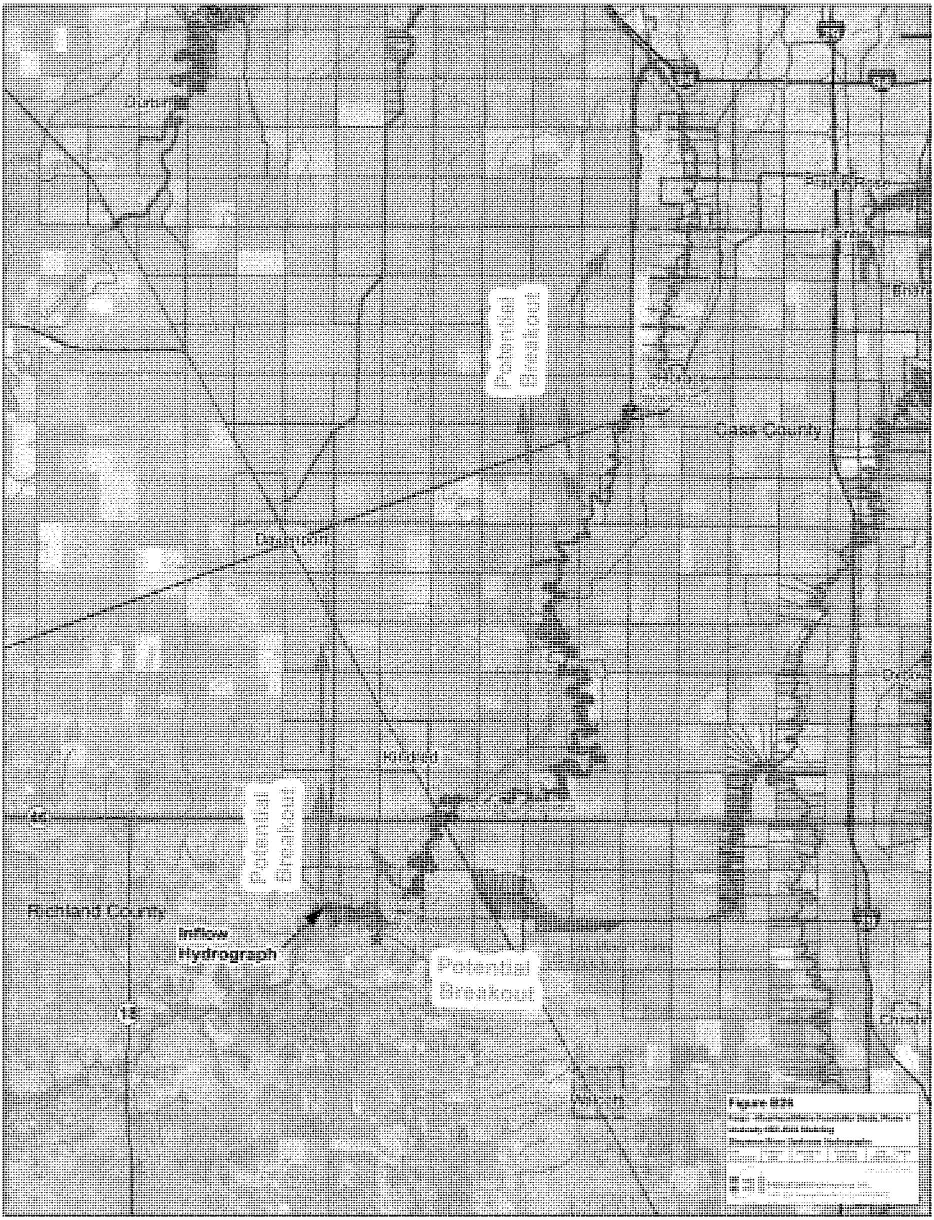
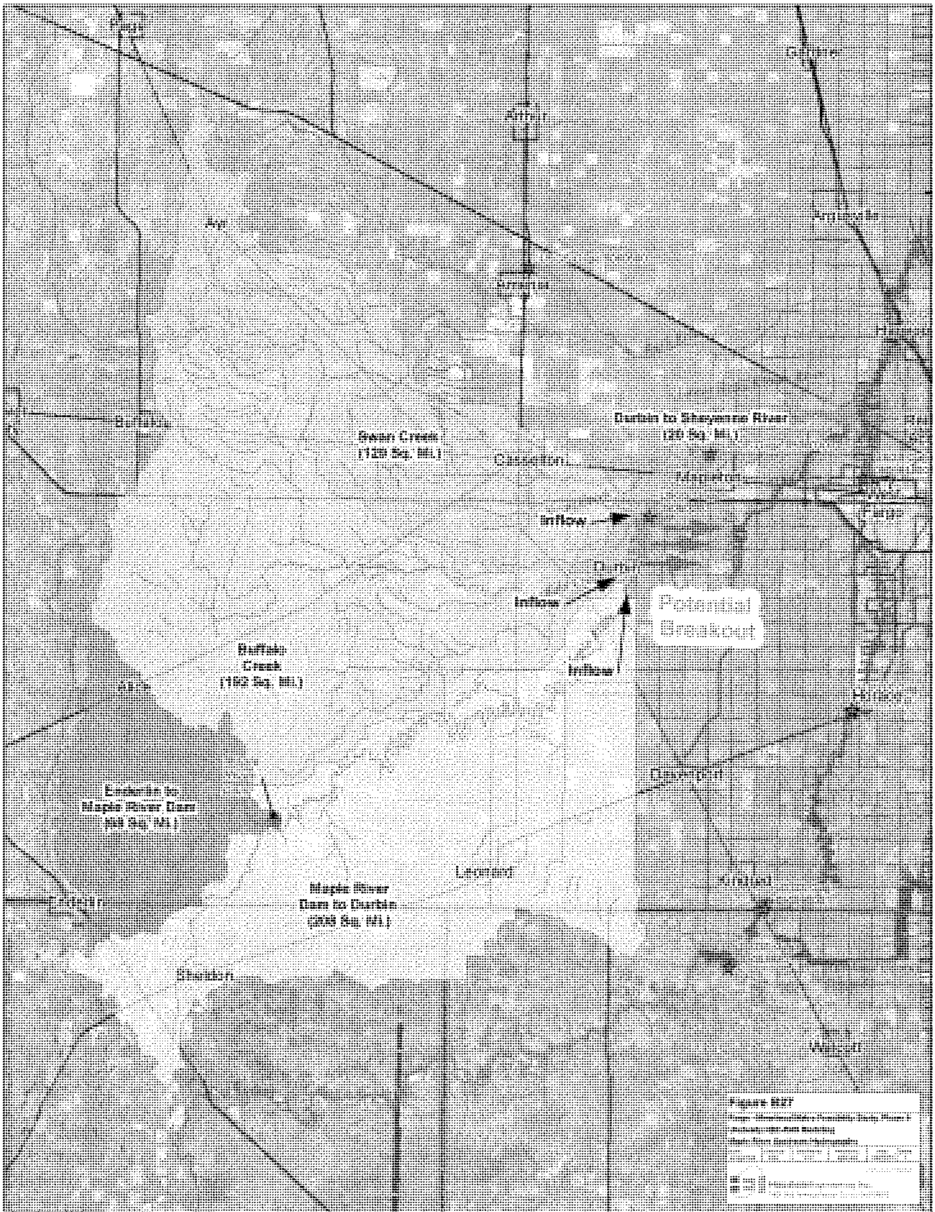

N
Drayton
Grand Forks
Thompson
Halstad
Fargo
Hickson
See Figure B27
for Detail
See Figure B26
for Detail
Cavalier County
Pembina County
Kittson County
Walsh County
Marshall County
Pennington County
Grand Forks County
Red Lake County
Nelson County
Polk County
Steele County
Traill County
Norman County
Mahnomen County
Griggs County
Barnes County
Cass County
Clay County
Becker County
Richland County
Wilkin County
Otter
Sargent County
USGS Gages
USGS Gage Inflow Locations
USGS Gage/Balanced Hydrograph
Existing Conditions Model Cross Sections
Existing Conditions Model Reaches
Existing Conditions Model Storage Areas
City Boundaries
Counties
Figure B24
Fargo - Moorhead Metro Feasibility Study, Phase 4
Unsteady HEC-RAS Modeling
Observed USGS Gage Locations
HoustonEngineering Inc.

Figure B25

2009 Red River Upstream Inflow Hydrograph

See page B-16 within Appendix B


Cass County
Davenport
Kindred
Richland County
Inflow
Hydrograph
Potential
Breakout
Potential
Breakout
Potential
Breakout
46
18


Durbin to Sheyenne River
(39 Sq. Mi.)
Swan Creek
(129 Sq. Mi.)
Casselton
Mapleton
Inflow
Inflow
Potential
Breakout
Inflow
Buffalo
Creek
(192 Sq. Mi.)
Davenport
Leonard
Maple River
Dam to Durbin
Sheldon
Kindred
Buffalo
Arthur
Amenia
Argusville
Harwood
Fargo
Horace
Walcott
Figure B27

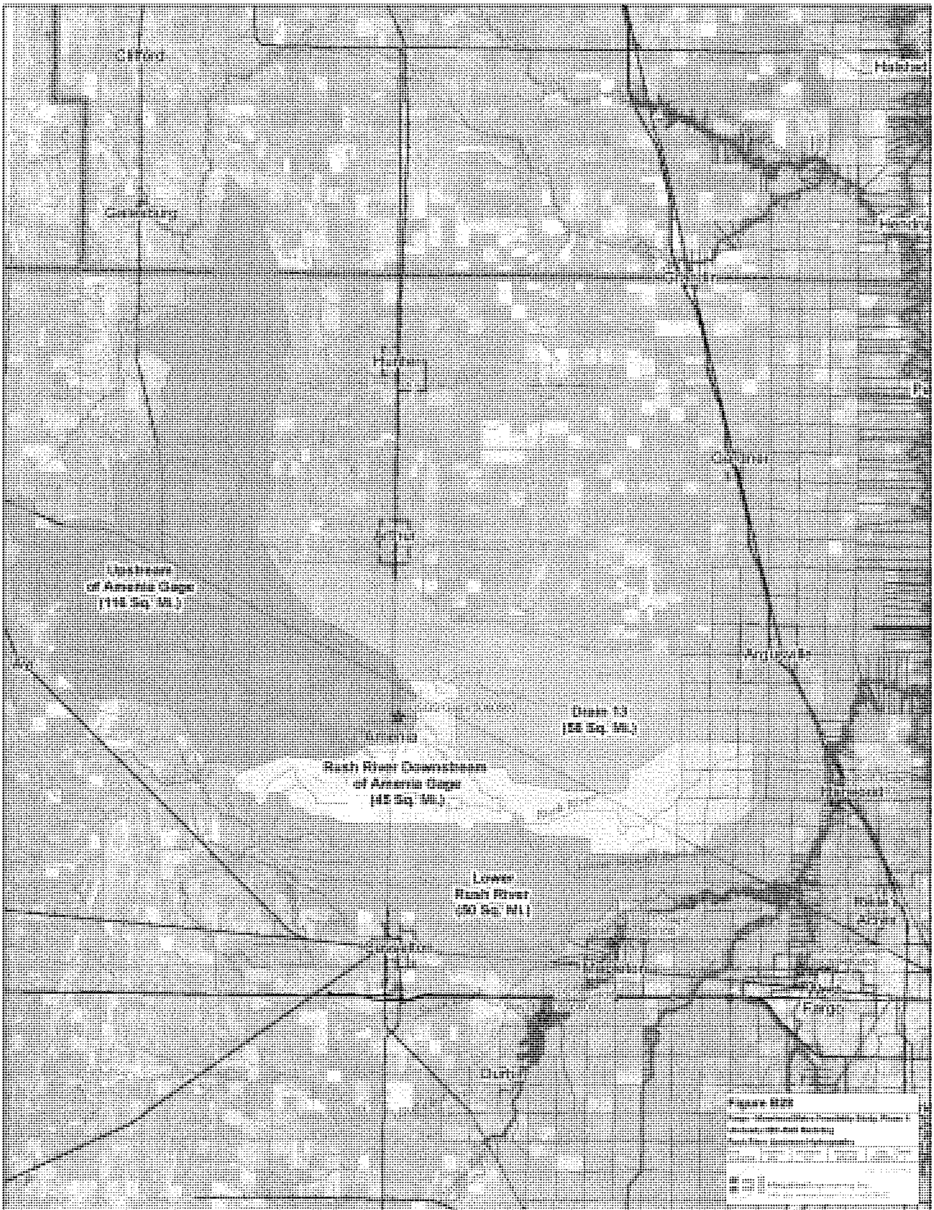
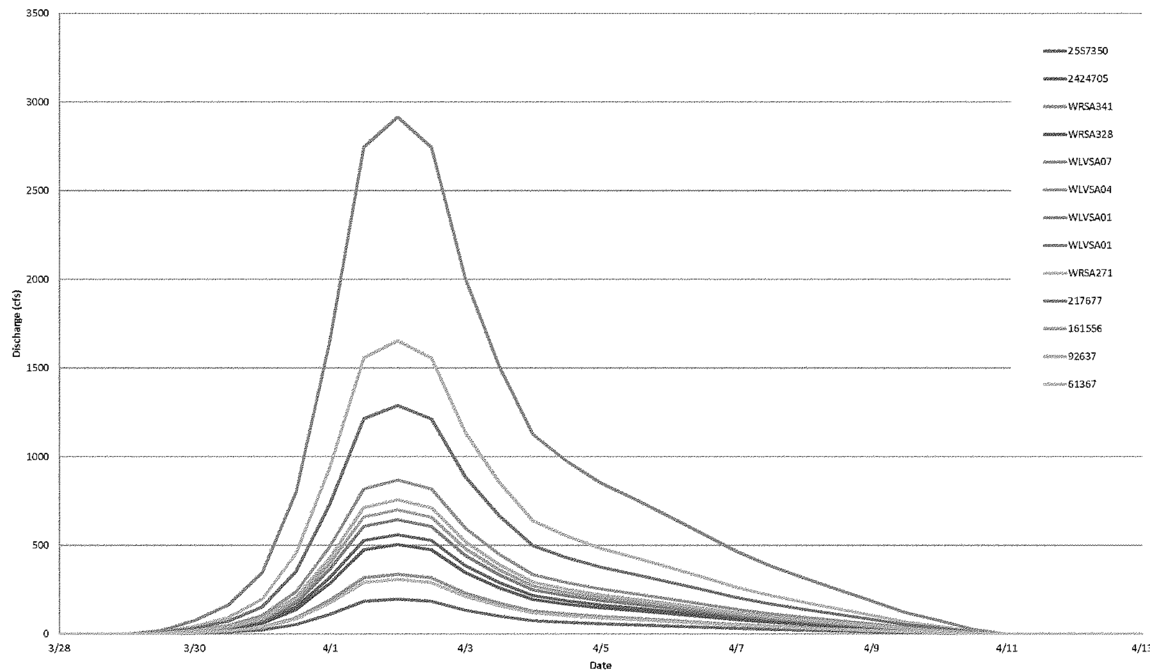
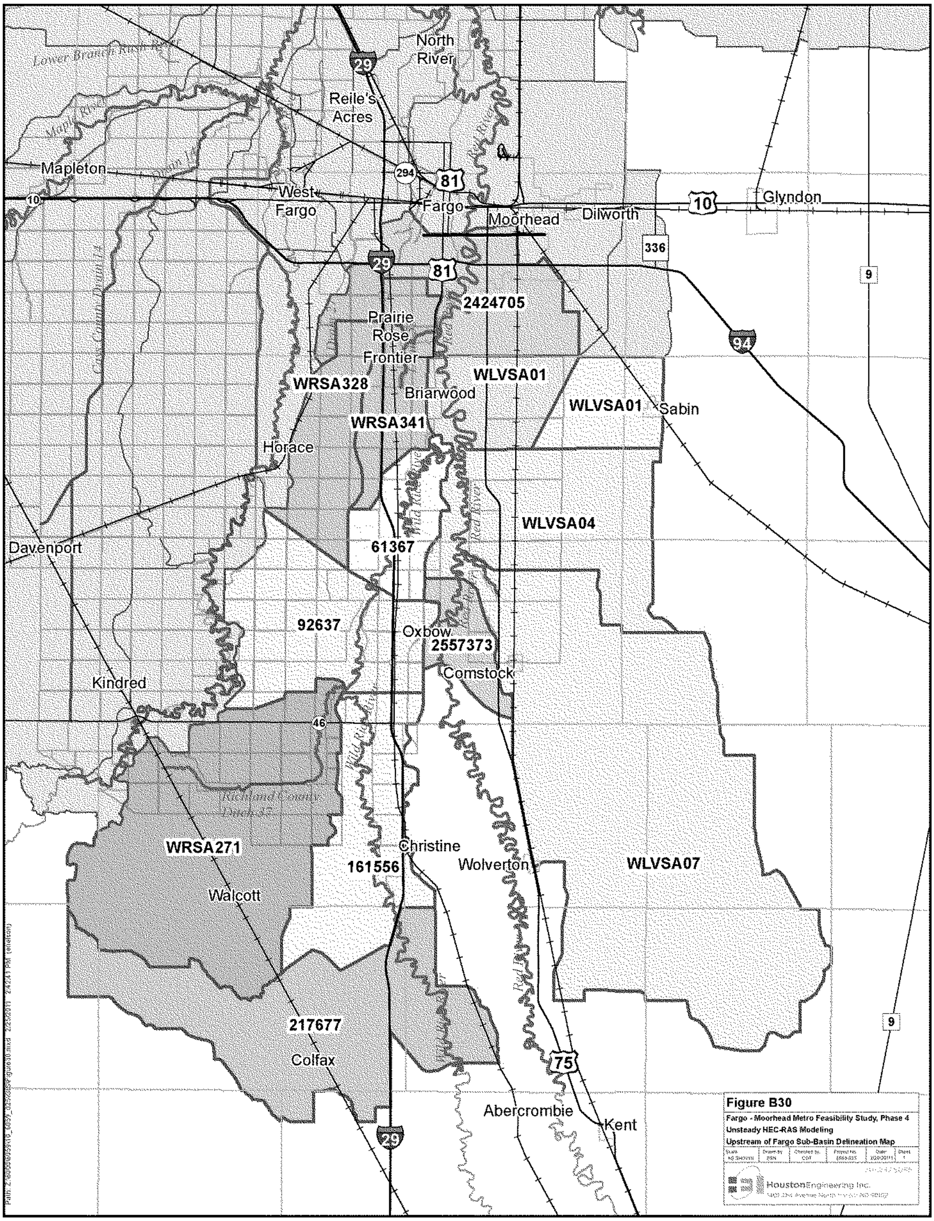

Clifford
Upstream
of Amenia Gage
Amenia
Drain 13
Rush River Downstream
of Amenia Gage
Lower
Rush River
Fargo

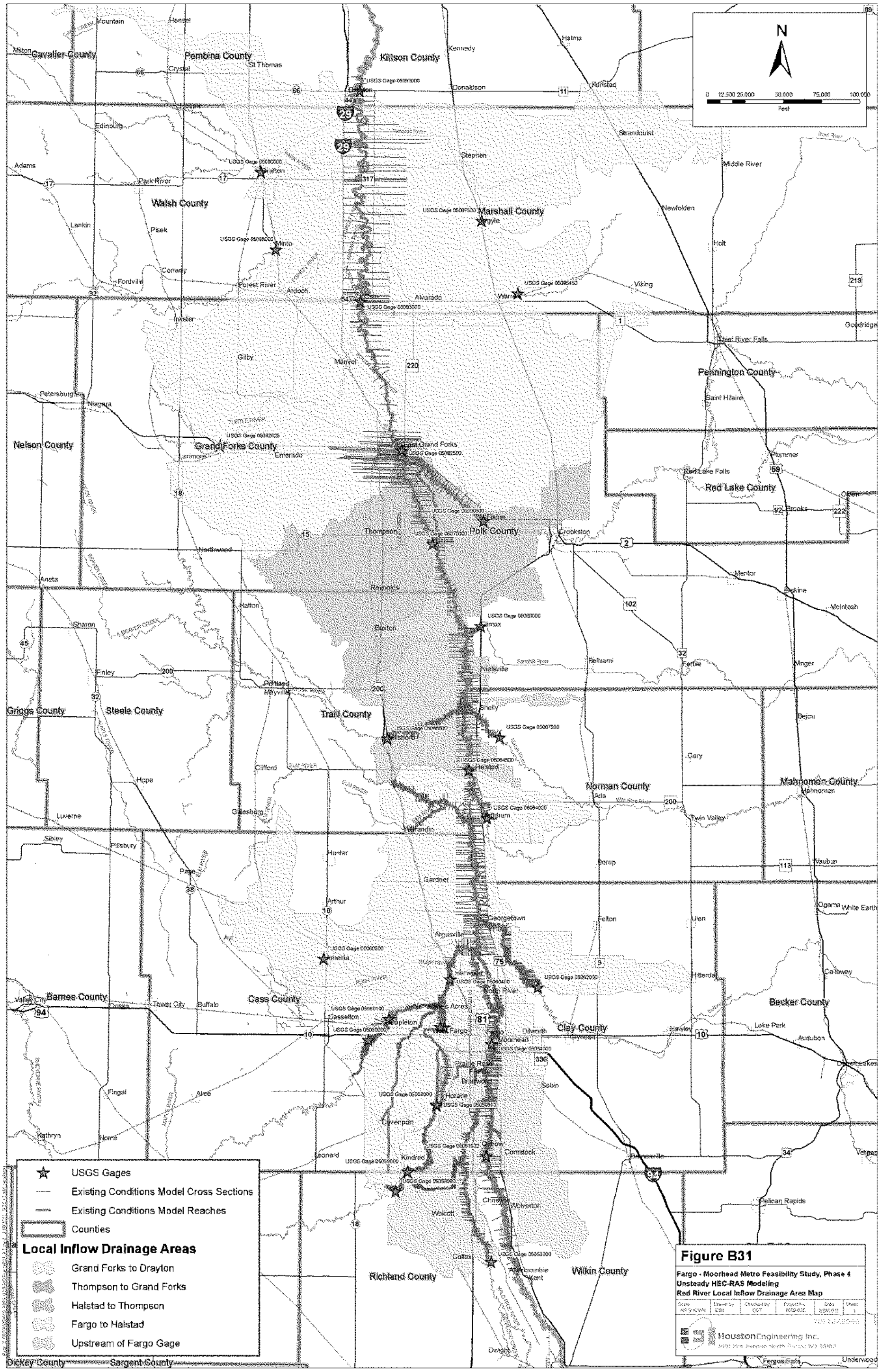
Figure B29 - Upstream of Fargo Gage Local Inflow Table and Hydrographs

River	Red River	Red River	Red River	Red River	Red River	Red River	Red River	Red River	WRRND	WRRND	WRRND	WRRND	WRRND
Name	Hickson to NDDIV	Rose Coulee to Fargo Gage	Drain 53	Drain 27	Wolverton Creek	MN Local NDDIV to WRRND	MN Local WRRND to Rose Coulee - A	MN Local WRRND to Rose Coulee - B	Richland Co. West	Abercrombie to I-29	I-29 to 104884	92637 to ND DIV	ND DIV to RRN
Sta_From	**2557350**	**2424705**	**WRSA341**	**WRSA328**	**WLVSA07**	**WLVSA04**	**WLVSA01**	**WLVSA01**	**WRSA271**	**217677**	**161556**	**92637**	**61367**
Sta_To	2531315	2388223	Storage Area	Storage Area	Storage Area	Storage Area	Storage Area	Storage Area	Storage Area	171972	103632	74680	10468
Area_SM	7	20	12	18	104	31	12	11	59	46	25	27	11

Ungaged Local Inflows to Fargo




Lower Branch Rush River
Maple River
North River
Reile's Acres
Mapleton
West Fargo
Fargo
Moorhead
Dilworth
Glyndon
Prairie Rose
Frontier
Briarwood
Horace
Davenport
Sabin
Oxbow
Comstock
Kindred
Christine
Wolverton
Walcott
Colfax
Abercrombie
Kent
Richland County Drain 37
Cass County Drain 14
Wild Rice River
Red River
29
294
81
10
336
9
94
46
75
2424705
WLVSA01
WLVSA01
WRSA328
WRSA341
WLVSA04
61367
92637
2557373
WRSA271
161556
WLVSA07
217677
Figure B30
Fargo - Moorhead Metro Feasibility Study, Phase 4
Unsteady HEC-RAS Modeling
Upstream of Fargo Sub-Basin Delineation Map
HoustonEngineering Inc.


USGS Gages
Existing Conditions Model Cross Sections
Existing Conditions Model Reaches
Counties
Local Inflow Drainage Areas
Grand Forks to Drayton
Thompson to Grand Forks
Halstad to Thompson
Fargo to Halstad
Upstream of Fargo Gage
Figure B31
Fargo - Moorhead Metro Feasibility Study, Phase 4
Unsteady HEC-RAS Modeling
Red River Local Inflow Drainage Area Map
HoustonEngineering Inc.
Cavalier County
Pembina County
Kittson County
Walsh County
Marshall County
Pennington County
Nelson County
Grand Forks County
Red Lake County
Polk County
Griggs County
Steele County
Traill County
Norman County
Mahnomen County
Barnes County
Cass County
Clay County
Becker County
Richland County
Wilkin County
Dickey County
Sargent County

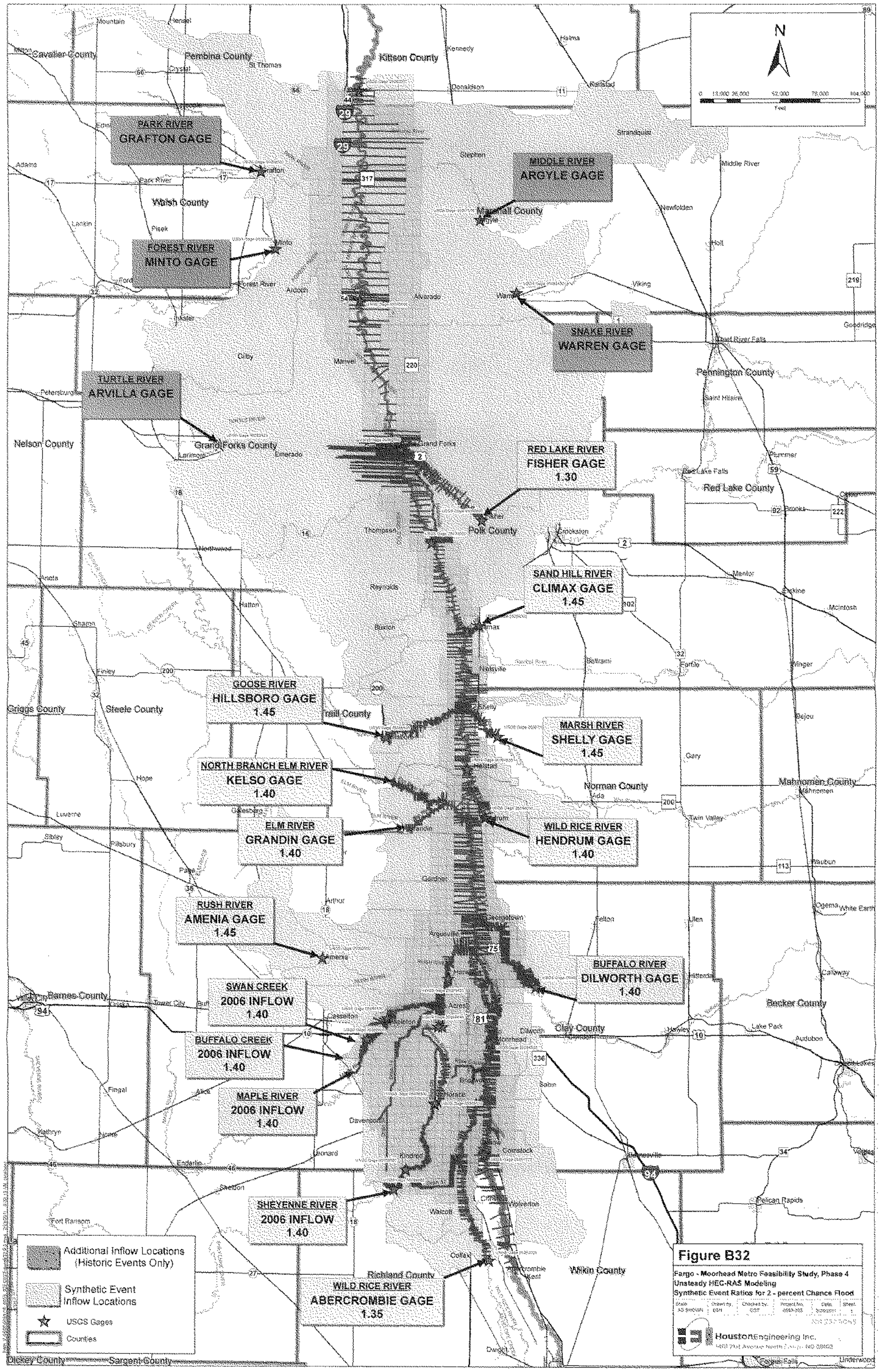
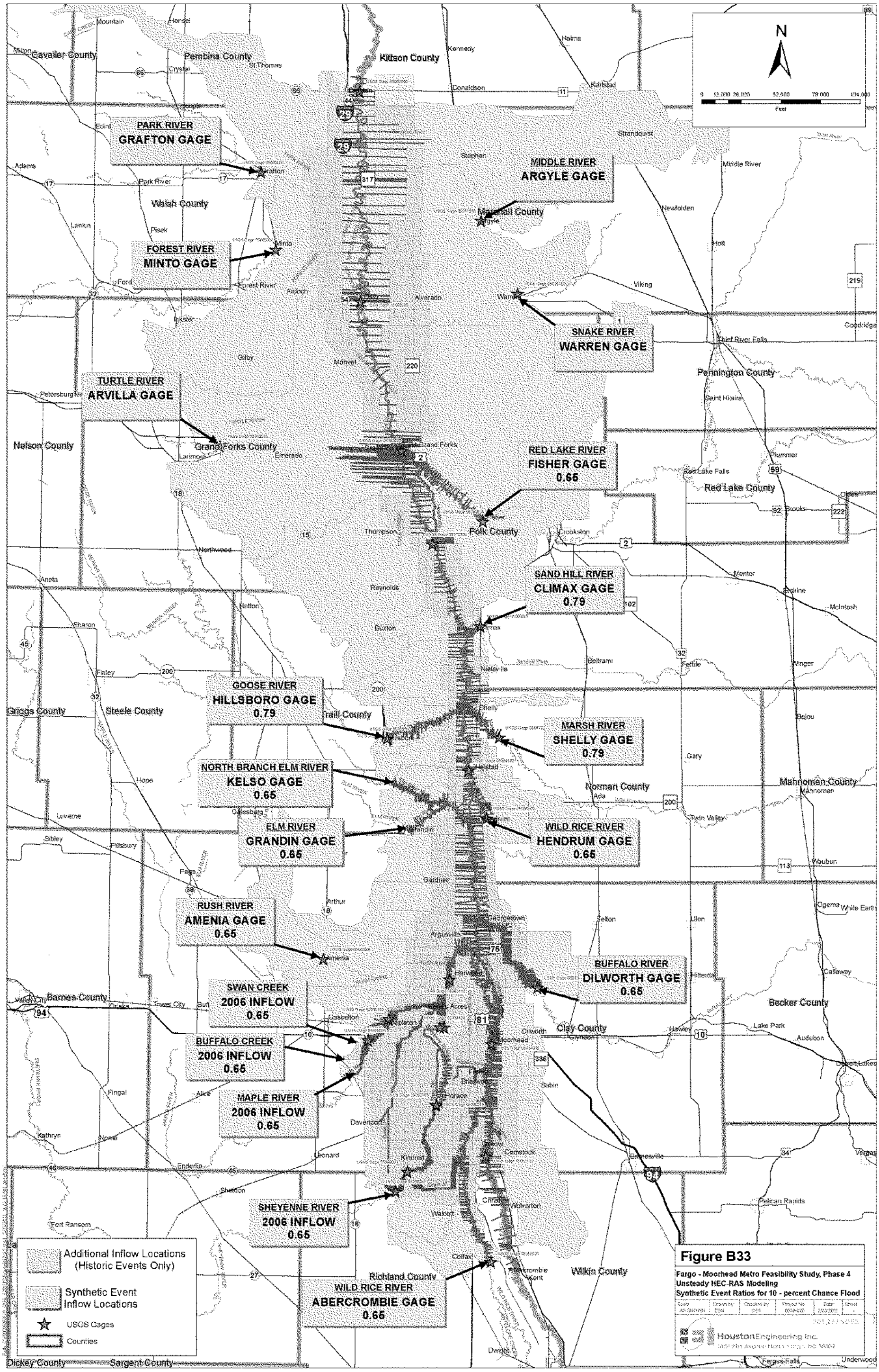

PARK RIVER
GRAFTON GAGE
MIDDLE RIVER
ARGYLE GAGE
FOREST RIVER
MINTO GAGE
SNAKE RIVER
WARREN GAGE
TURTLE RIVER
ARVILLA GAGE
RED LAKE RIVER
FISHER GAGE
1.30
SAND HILL RIVER
CLIMAX GAGE
1.45
GOOSE RIVER
HILLSBORO GAGE
1.45
MARSH RIVER
SHELLY GAGE
1.45
NORTH BRANCH ELM RIVER
KELSO GAGE
1.40
ELM RIVER
GRANDIN GAGE
1.40
WILD RICE RIVER
HENDRUM GAGE
1.40
RUSH RIVER
AMENIA GAGE
1.45
BUFFALO RIVER
DILWORTH GAGE
1.40
SWAN CREEK
2006 INFLOW
1.40
BUFFALO CREEK
2006 INFLOW
1.40
MAPLE RIVER
2006 INFLOW
1.40
SHEYENNE RIVER
2006 INFLOW
1.40
WILD RICE RIVER
ABERCROMBIE GAGE
1.35
Kittson County
Pembina County
Cavalier County
Walsh County
Marshall County
Pennington County
Nelson County
Grand Forks County
Red Lake County
Polk County
Griggs County
Steele County
Traill County
Norman County
Mahnomen County
Barnes County
Clay County
Becker County
Richland County
Wilkin County
Dickey County
Sargent County
Additional Inflow Locations
(Historic Events Only)
Synthetic Event
Inflow Locations
USGS Gages
Counties
N
Feet
Figure B32
Fargo - Moorhead Metro Feasibility Study, Phase 4
Unsteady HEC-RAS Modeling
Synthetic Event Ratios for 2 - percent Chance Flood
HoustonEngineering Inc.

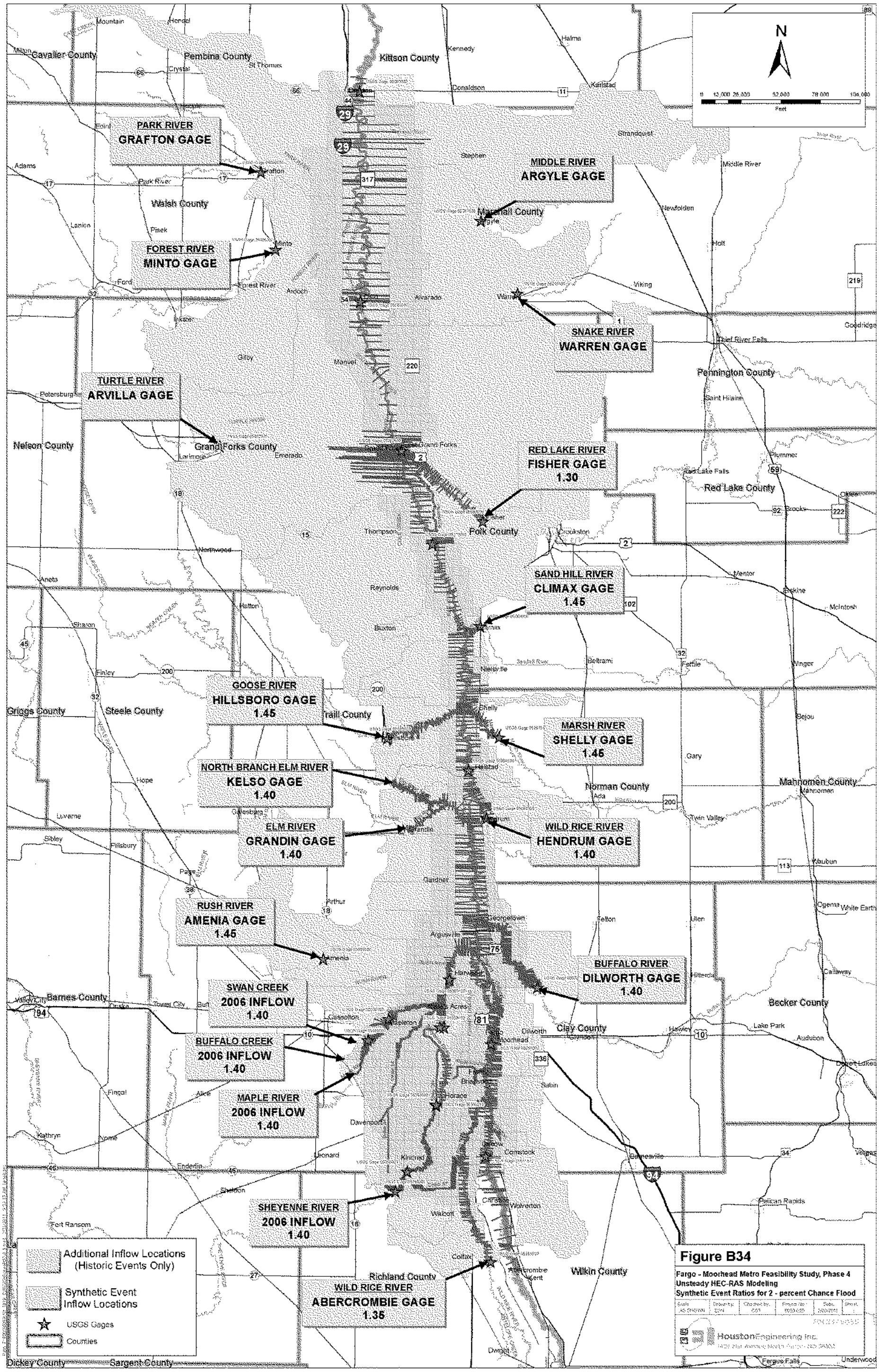
Figure B32

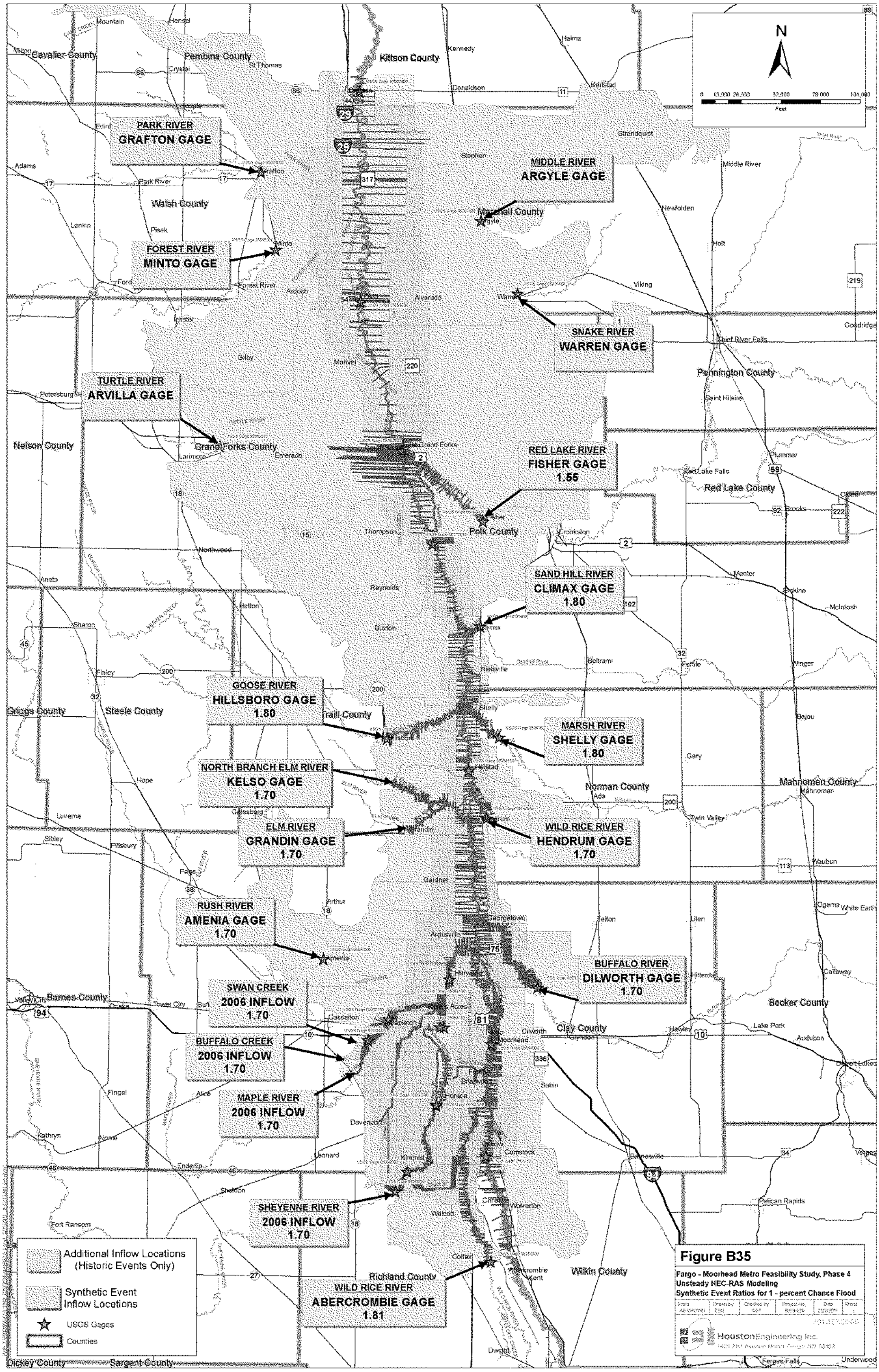
Ungaged Local Inflow Hydrograph Example

See page B-22 within Appendix B

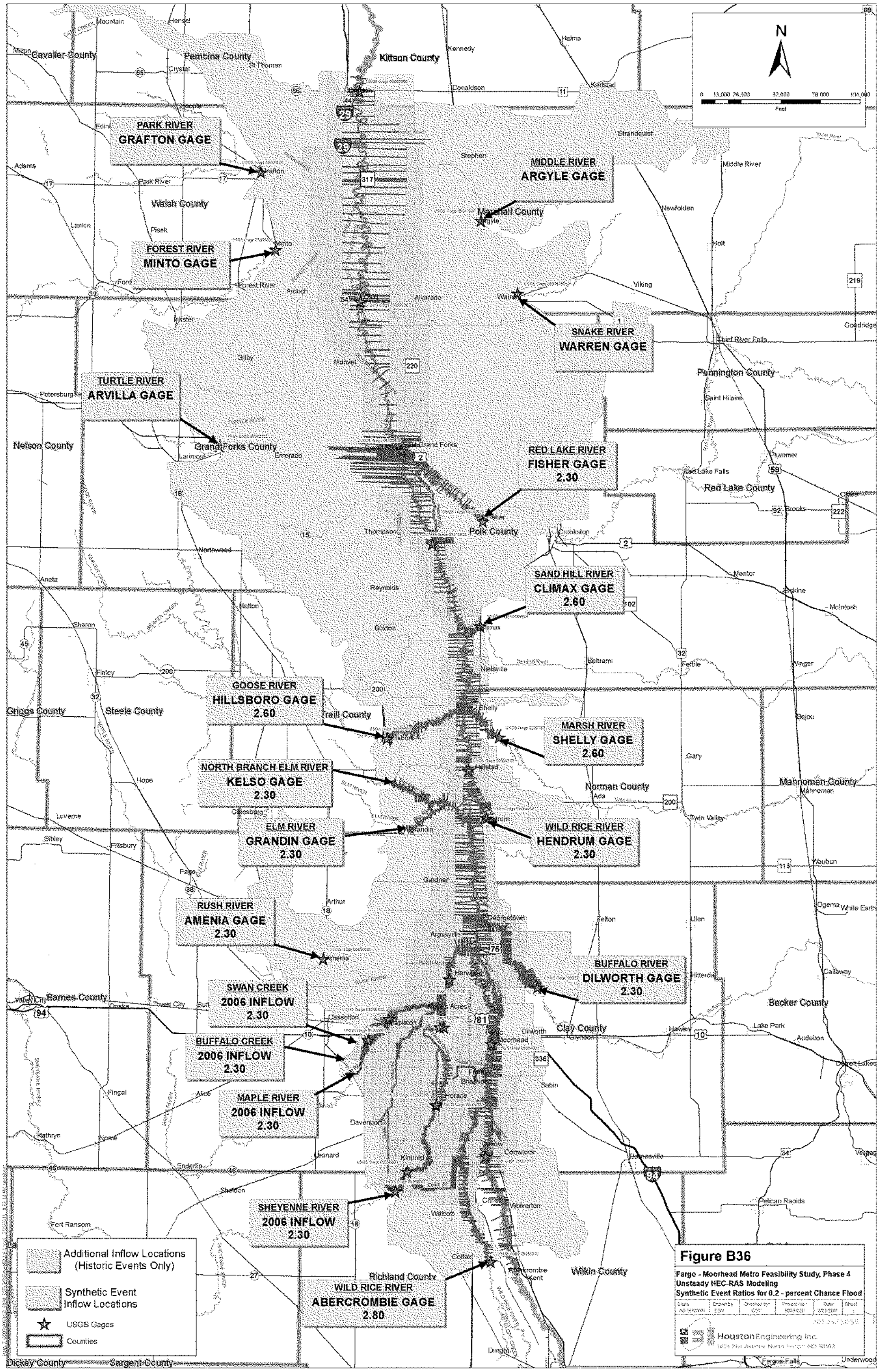


N
PARK RIVER
GRAFTON GAGE
MIDDLE RIVER
ARGYLE GAGE
FOREST RIVER
MINTO GAGE
SNAKE RIVER
WARREN GAGE
TURTLE RIVER
ARVILLA GAGE
RED LAKE RIVER
FISHER GAGE
0.65
SAND HILL RIVER
CLIMAX GAGE
0.79
GOOSE RIVER
HILLSBORO GAGE
0.79
MARSH RIVER
SHELLY GAGE
0.79
NORTH BRANCH ELM RIVER
KELSO GAGE
0.65
ELM RIVER
GRANDIN GAGE
0.65
WILD RICE RIVER
HENDRUM GAGE
0.65
RUSH RIVER
AMENIA GAGE
0.65
BUFFALO RIVER
DILWORTH GAGE
0.65
SWAN CREEK
2006 INFLOW
0.65
BUFFALO CREEK
2006 INFLOW
0.65
MAPLE RIVER
2006 INFLOW
0.65
SHEYENNE RIVER
2006 INFLOW
0.65
WILD RICE RIVER
ABERCROMBIE GAGE
0.65
Cavalier County
Pembina County
Kittson County
Walsh County
Marshall County
Pennington County
Nelson County
Grand Forks County
Red Lake County
Polk County
Griggs County
Steele County
Traill County
Norman County
Mahnomen County
Barnes County
Becker County
Clay County
Richland County
Wilkin County
Dickey County
Sargent County
Additional Inflow Locations
(Historic Events Only)
Synthetic Event
Inflow Locations
USGS Gages
Counties
Figure B33
Fargo - Moorhead Metro Feasibility Study, Phase 4
Unsteady HEC-RAS Modeling
Synthetic Event Ratios for 10 - percent Chance Flood
HoustonEngineering Inc.

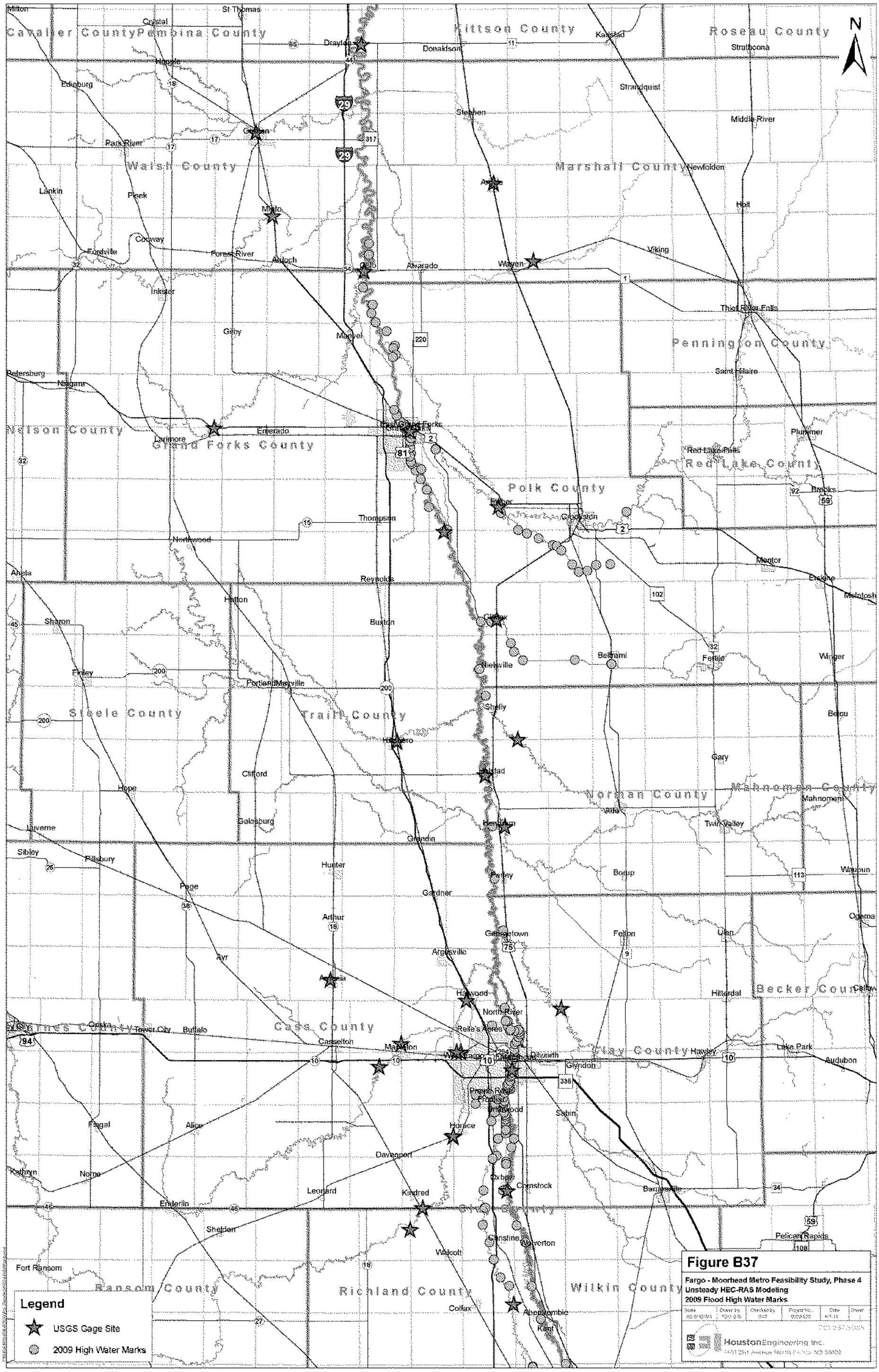

PARK RIVER
GRAFTON GAGE
MIDDLE RIVER
ARGYLE GAGE
FOREST RIVER
MINTO GAGE
SNAKE RIVER
WARREN GAGE
TURTLE RIVER
ARVILLA GAGE
RED LAKE RIVER
FISHER GAGE
1.30
SAND HILL RIVER
CLIMAX GAGE
1.45
GOOSE RIVER
HILLSBORO GAGE
1.45
MARSH RIVER
SHELLY GAGE
1.45
NORTH BRANCH ELM RIVER
KELSO GAGE
1.40
ELM RIVER
GRANDIN GAGE
1.40
WILD RICE RIVER
HENDRUM GAGE
1.40
RUSH RIVER
AMENIA GAGE
1.45
BUFFALO RIVER
DILWORTH GAGE
1.40
SWAN CREEK
2006 INFLOW
1.40
BUFFALO CREEK
2006 INFLOW
1.40
MAPLE RIVER
2006 INFLOW
1.40
SHEYENNE RIVER
2006 INFLOW
1.40
WILD RICE RIVER
ABERCROMBIE GAGE
1.35
Cavalier County
Pembina County
Kittson County
Walsh County
Marshall County
Pennington County
Nelson County
Grand Forks County
Red Lake County
Polk County
Griggs County
Steele County
Traill County
Norman County
Mahnomen County
Barnes County
Clay County
Becker County
Richland County
Wilkin County
Dickey County
Sargent County
N
Additional Inflow Locations
(Historic Events Only)
Synthetic Event
Inflow Locations
USGS Gages
Counties
Figure B34
Fargo - Moorhead Metro Feasibility Study, Phase 4
Unsteady HEC-RAS Modeling
Synthetic Event Ratios for 2 - percent Chance Flood
HoustonEngineering Inc.



N
PARK RIVER
GRAFTON GAGE
MIDDLE RIVER
ARGYLE GAGE
FOREST RIVER
MINTO GAGE
SNAKE RIVER
WARREN GAGE
TURTLE RIVER
ARVILLA GAGE
RED LAKE RIVER
FISHER GAGE
1.55
SAND HILL RIVER
CLIMAX GAGE
1.80
GOOSE RIVER
HILLSBORO GAGE
1.80
MARSH RIVER
SHELLY GAGE
1.80
NORTH BRANCH ELM RIVER
KELSO GAGE
1.70
ELM RIVER
GRANDIN GAGE
1.70
WILD RICE RIVER
HENDRUM GAGE
1.70
RUSH RIVER
AMENIA GAGE
1.70
BUFFALO RIVER
DILWORTH GAGE
1.70
SWAN CREEK
2006 INFLOW
1.70
BUFFALO CREEK
2006 INFLOW
1.70
MAPLE RIVER
2006 INFLOW
1.70
SHEYENNE RIVER
2006 INFLOW
1.70
WILD RICE RIVER
ABERCROMBIE GAGE
1.81
Kittson County
Cavalier County
Pembina County
Walsh County
Marshall County
Pennington County
Nelson County
Grand Forks County
Red Lake County
Polk County
Griggs County
Steele County
Traill County
Norman County
Mahnomen County
Barnes County
Clay County
Becker County
Richland County
Wilkin County
Dickey County
Sargent County
Additional Inflow Locations
(Historic Events Only)
Synthetic Event
Inflow Locations
USGS Gages
Counties
Figure B35
Fargo - Moorhead Metro Feasibility Study, Phase 4
Unsteady HEC-RAS Modeling
Synthetic Event Ratios for 1 - percent Chance Flood
HoustonEngineering Inc.



PARK RIVER
GRAFTON GAGE
MIDDLE RIVER
ARGYLE GAGE
FOREST RIVER
MINTO GAGE
SNAKE RIVER
WARREN GAGE
TURTLE RIVER
ARVILLA GAGE
RED LAKE RIVER
FISHER GAGE
2.30
SAND HILL RIVER
CLIMAX GAGE
2.60
GOOSE RIVER
HILLSBORO GAGE
2.60
MARSH RIVER
SHELLY GAGE
2.60
NORTH BRANCH ELM RIVER
KELSO GAGE
2.30
ELM RIVER
GRANDIN GAGE
2.30
WILD RICE RIVER
HENDRUM GAGE
2.30
RUSH RIVER
AMENIA GAGE
2.30
BUFFALO RIVER
DILWORTH GAGE
2.30
SWAN CREEK
2006 INFLOW
2.30
BUFFALO CREEK
2006 INFLOW
2.30
MAPLE RIVER
2006 INFLOW
2.30
SHEYENNE RIVER
2006 INFLOW
2.30
WILD RICE RIVER
ABERCROMBIE GAGE
2.80
Cavalier County
Pembina County
Kittson County
Walsh County
Marshall County
Pennington County
Nelson County
Grand Forks County
Red Lake County
Polk County
Griggs County
Steele County
Traill County
Norman County
Mahnomen County
Barnes County
Clay County
Becker County
Richland County
Wilkin County
Dickey County
Sargent County
Additional Inflow Locations
(Historic Events Only)
Synthetic Event
Inflow Locations
USGS Gages
Counties
N
Figure B36
Fargo - Moorhead Metro Feasibility Study, Phase 4
Unsteady HEC-RAS Modeling
Synthetic Event Ratios for 0.2 - percent Chance Flood
Houston Engineering Inc.


N
Kittson County
Roseau County
Pembina County
Walsh County
Marshall County
Pennington County
Nelson County
Grand Forks County
Polk County
Red Lake County
Steele County
Traill County
Norman County
Mahnomen County
Becker County
Cass County
Clay County
Ransom County
Richland County
Wilkin County
Drayton
Donaldson
Karlstad
Strathcona
Grafton
Stephen
Argyle
Warren
Oslo
Alvarado
Thief River Falls
Manvel
Emerado
Crookston
Fisher
Thompson
Climax
Nielsville
Beltrami
Shelly
Hillsboro
Halstad
Hendrum
Perley
Georgetown
Harwood
North River
Casselton
Mapleton
West Fargo
Dilworth
Glyndon
Moorhead
Sabin
Horace
Davenport
Oxbow
Comstock
Kindred
Barnesville
Christine
Wolverton
Walcott
Abercrombie
Pelican Rapids
Figure B37
Fargo - Moorhead Metro Feasibility Study, Phase 4
Unsteady HEC-RAS Modeling
2009 Flood High Water Marks
Houston Engineering Inc.
Legend
USGS Gage Site
2009 High Water Marks

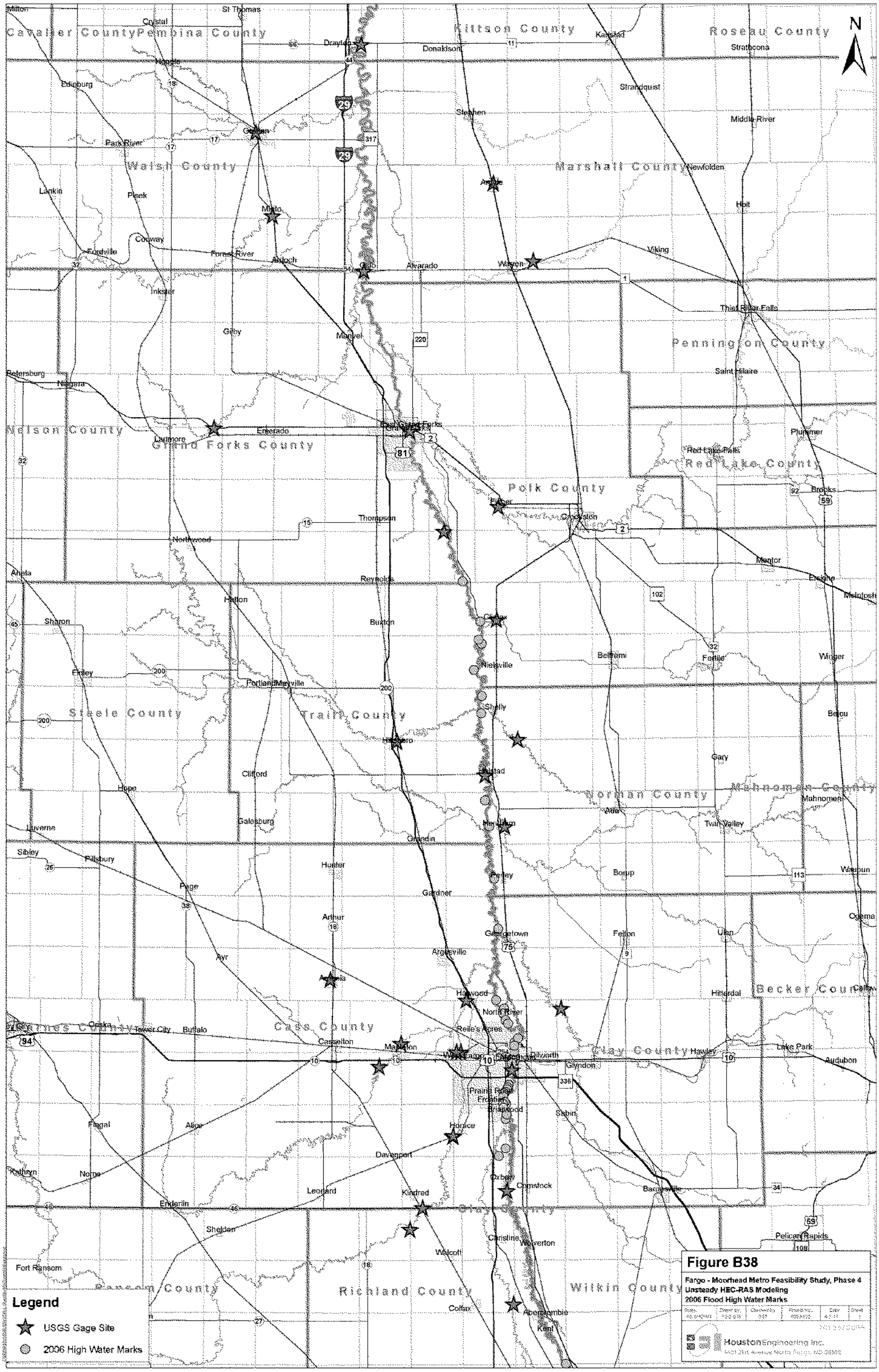


Figure B38
Fargo - Moorhead Metro Feasibility Study, Phase 4
Unsteady HEC-RAS Modeling
2006 Flood High Water Marks
Houston Engineering Inc.
Legend
USGS Gage Site
2006 High Water Marks
N
Kittson County
Roseau County
Marshall County
Pennington County
Red Lake County
Polk County
Walsh County
Nelson County
Grand Forks County
Steele County
Traill County
Norman County
Mahnomen County
Becker County
Clay County
Cass County
Wilkin County
Richland County
Drayton
Donaldson
Grafton
Minto
Oslo
Alvarado
Warren
Thief River Falls
Grand Forks
East Grand Forks
Crookston
Thompson
Hillsboro
Halstad
Hendrum
Perley
Georgetown
Harwood
Moorhead
Casselton
Mapleton
Horace
Kindred
Davenport
Comstock
Wolverton
Abercrombie
Kent
Barnesville
Pelican Rapids

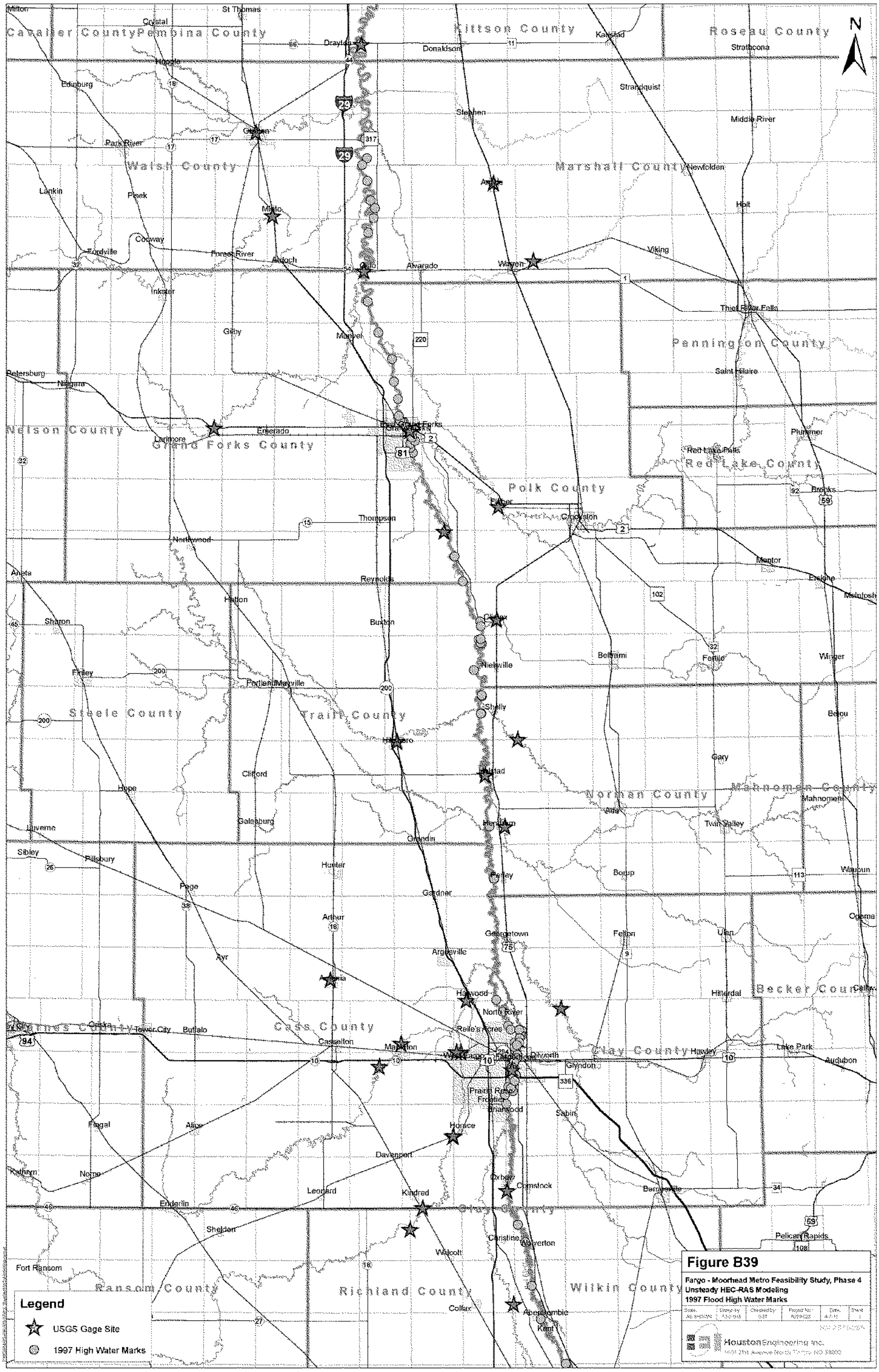


Figure B39
Fargo - Moorhead Metro Feasibility Study, Phase 4
Unsteady HEC-RAS Modeling
1997 Flood High Water Marks
Legend
USGS Gage Site
1997 High Water Marks
Houston Engineering Inc.
Cavalier County
Pembina County
Kittson County
Roseau County
Walsh County
Marshall County
Pennington County
Nelson County
Grand Forks County
Red Lake County
Polk County
Steele County
Traill County
Norman County
Mahnomen County
Becker County
Cass County
Clay County
Barnes County
Ransom County
Richland County
Wilkin County
Drayton
Grafton
Minto
Oslo
Alvarado
Warren
Argyle
Stephen
Thief River Falls
East Grand Forks
Grand Forks
Crookston
Fisher
Thompson
Reynolds
Climax
Nielsville
Shelly
Hillsboro
Halstad
Hendrum
Perley
Georgetown
Harwood
North River
Reile's Acres
West Fargo
Fargo
Moorhead
Dilworth
Glyndon
Mapleton
Casselton
Prairie Rose
Frontier
Briarwood
Horace
Davenport
Kindred
Oxbow
Comstock
Christine
Wolverton
Abercrombie
Kent
Colfax
Walcott
Sheldon
Enderlin
Fort Ransom
Hawley
Lake Park
Audubon
Barnesville
Pelican Rapids
Sabin
Hitterdal
Felton
Ulen
Borup
Ada
Twin Valley
Gary
Fertile
Beltrami
Mentor
Erskine
Winger
Bejou
Plummer
Brooks
Red Lake Falls
Saint Hilaire
Viking
Newfolden
Holt
Middle River
Strandquist
Strathcona
Karlstad
Donaldson
St Thomas
Crystal
Hoople
Edinburg
Park River
Lankin
Pisek
Conway
Fordville
Forest River
Ardoch
Inkster
Gilby
Manvel
Petersburg
Niagara
Larimore
Emerado
Northwood
Aneta
Hatton
Buxton
Sharon
Finley
Portland
Mayville
Clifford
Hope
Galesburg
Grandin
Hunter
Luverne
Sibley
Pillsbury
Page
Arthur
Gardner
Argusville
Ayr
Tower City
Buffalo
Oriska
Fingal
Alice
Kathryn
Nome
Leonard
Milton
Figure B39

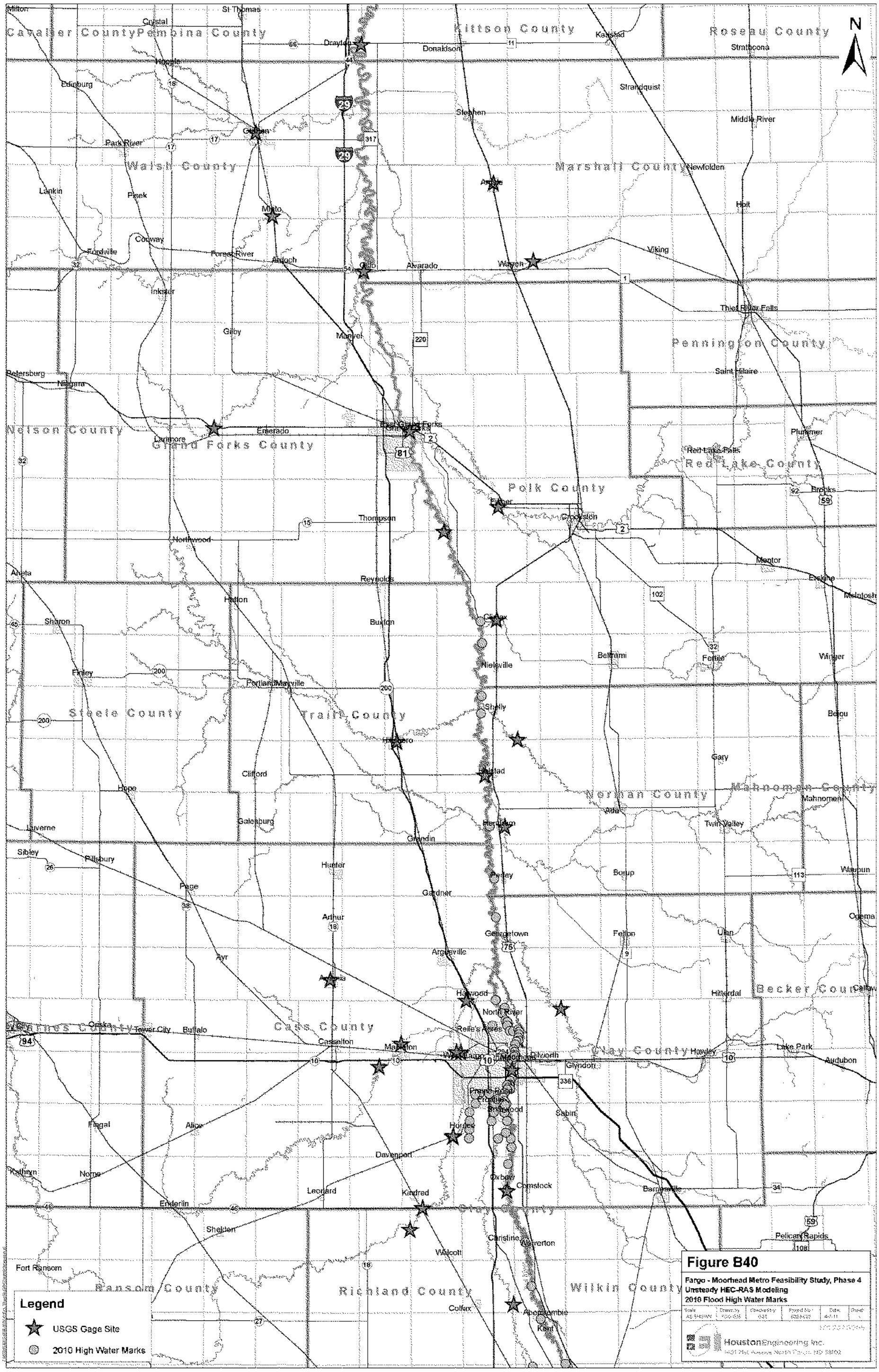
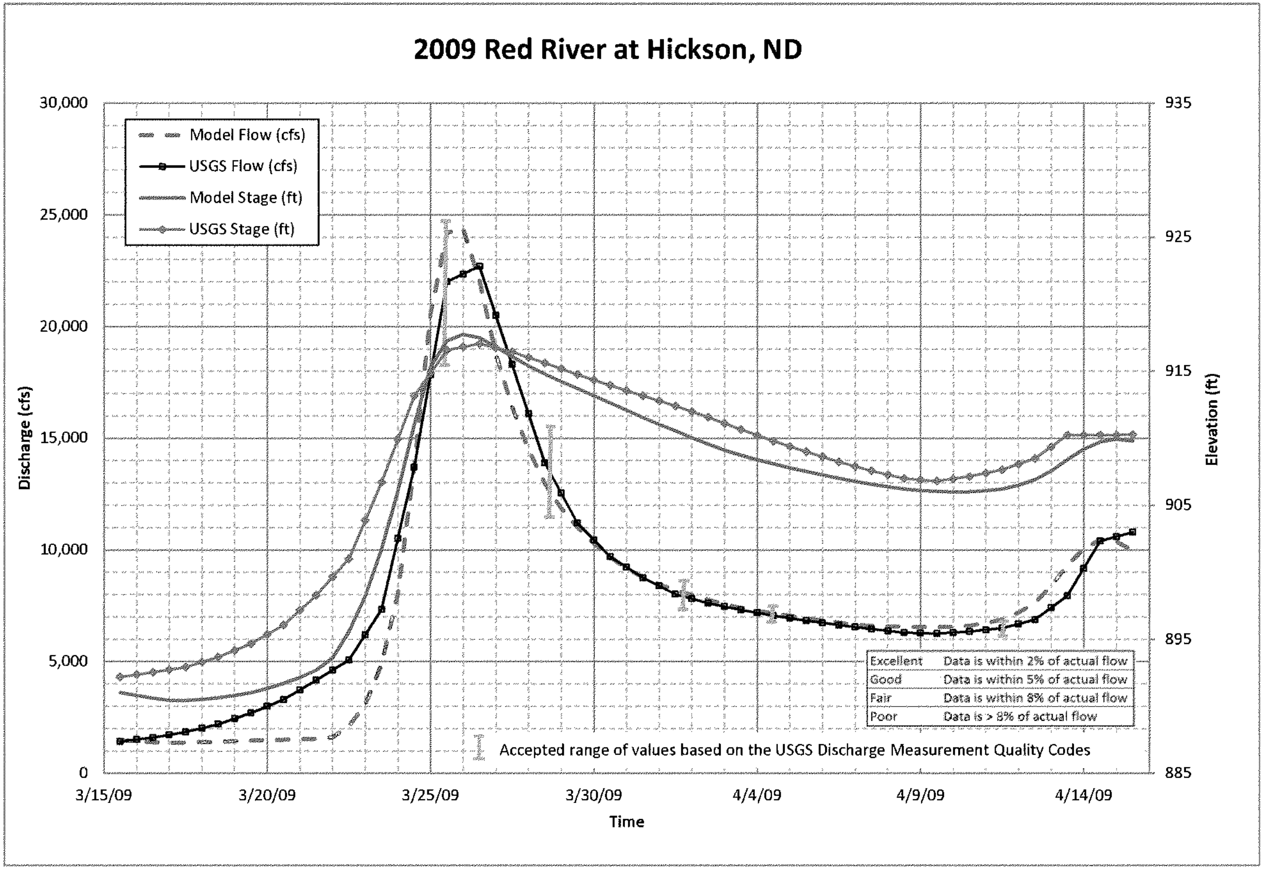


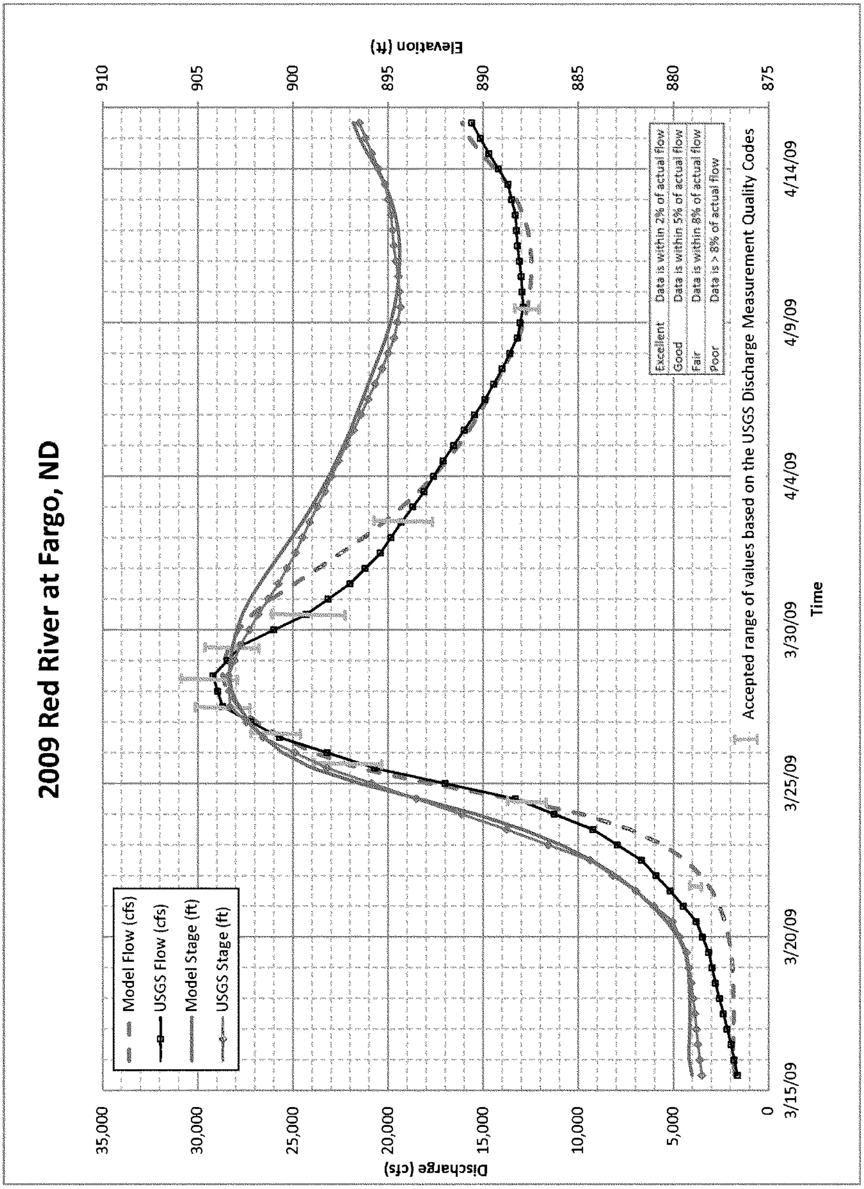
Figure B40
Fargo - Moorhead Metro Feasibility Study, Phase 4
Unsteady HEC-RAS Modeling
2010 Flood High Water Marks
Legend
USGS Gage Site
2010 High Water Marks
HoustonEngineering Inc.
Cavalier County
Pembina County
Kittson County
Roseau County
Walsh County
Marshall County
Pennington County
Nelson County
Grand Forks County
Polk County
Red Lake County
Steele County
Traill County
Norman County
Mahnomen County
Cass County
Clay County
Becker County
Ransom County
Richland County
Wilkin County
Drayton
Grafton
Minto
Oslo
East Grand Forks
Thompson
Crookston
Hillsboro
Halstad
Hendrum
Georgetown
Harwood
West Fargo
Moorhead
Fargo
Hickson
Kindred
Abercrombie
Wahpeton
Fergus Falls
Thief River Falls

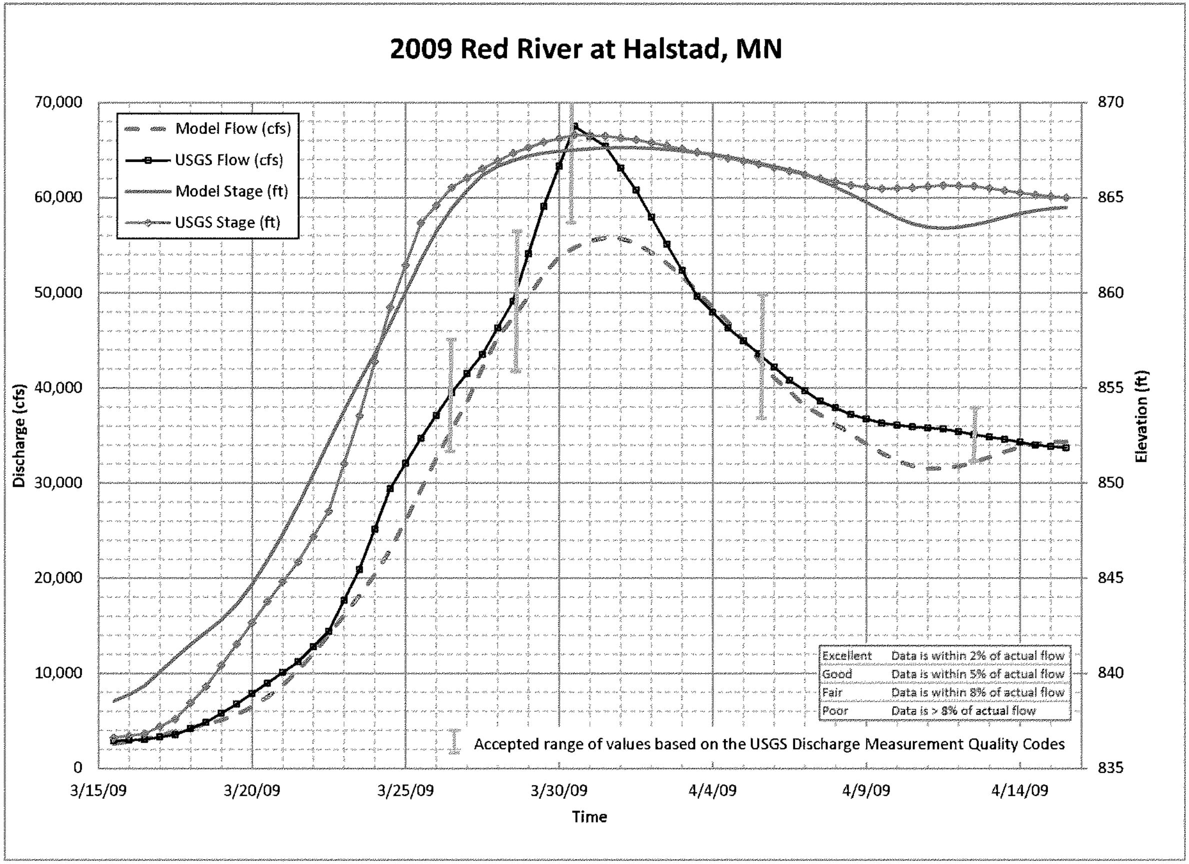
Appendix B – Hydraulics
Existing Condition

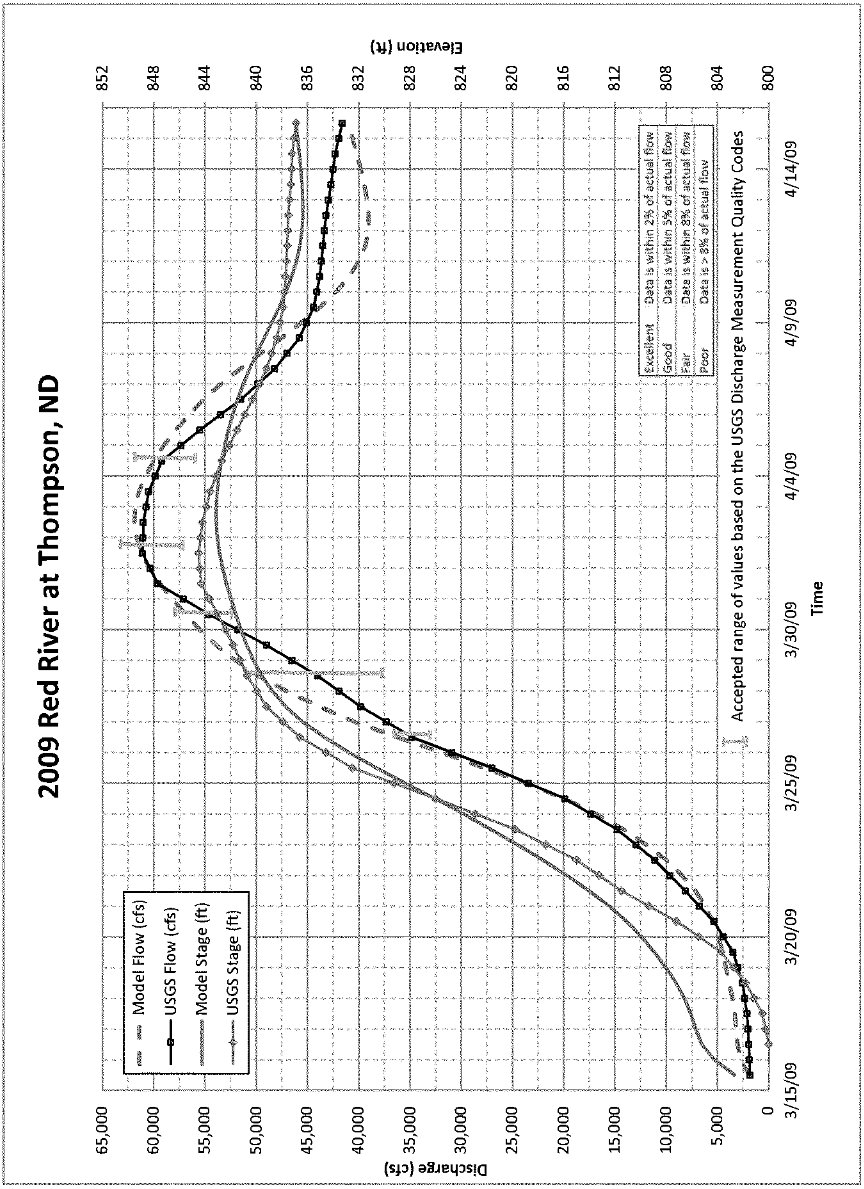
Exhibit A

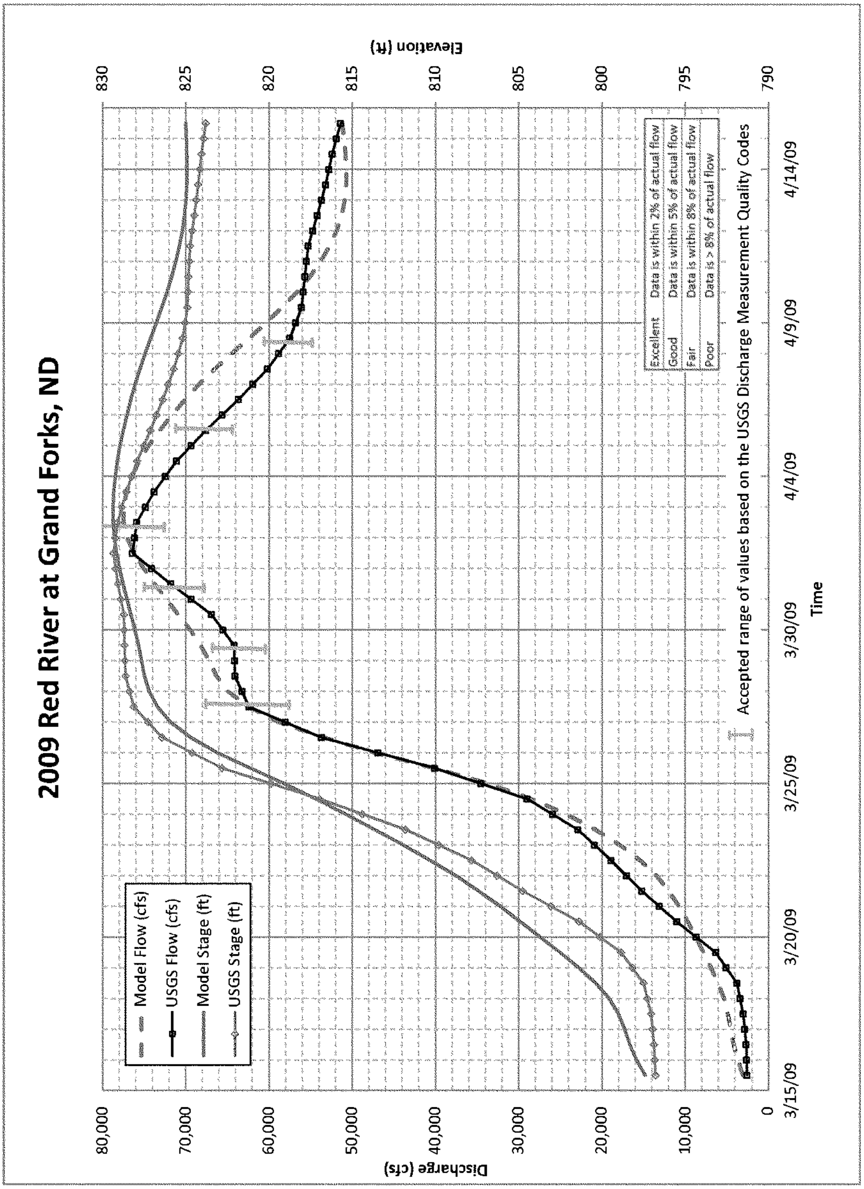
2009 Flood Calibration Discharge Hydrographs

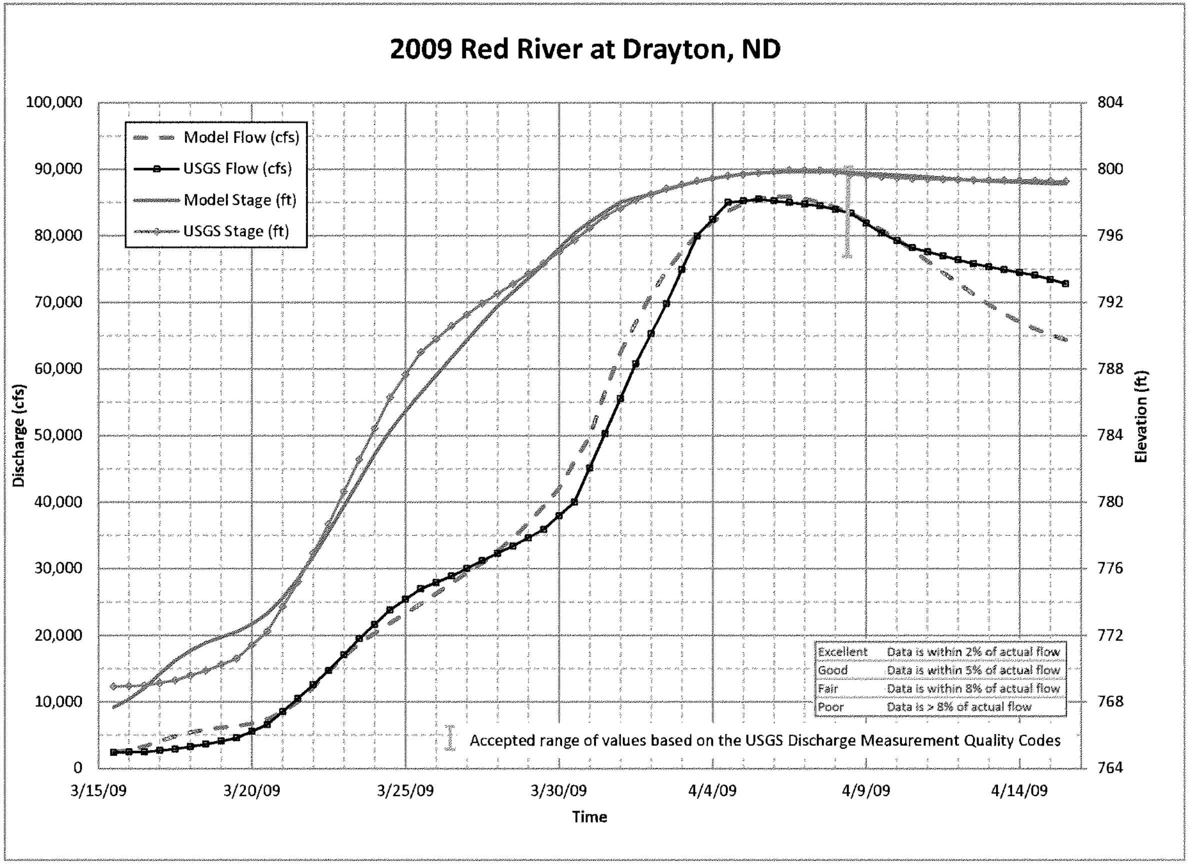

2009 Red River at Hickson, ND
Model Flow (cfs)
USGS Flow (cfs)
Model Stage (ft)
USGS Stage (ft)
Discharge (cfs)
30,000
25,000
20,000
15,000
10,000
5,000
0
Elevation (ft)
935
925
915
905
895
885
3/15/09
3/20/09
3/25/09
3/30/09
4/4/09
4/9/09
4/14/09
Time
Excellent Data is within 2% of actual flow
Good Data is within 5% of actual flow
Fair Data is within 8% of actual flow
Poor Data is > 8% of actual flow
Accepted range of values based on the USGS Discharge Measurement Quality Codes


2009 Red River at Fargo, ND
Model Flow (cfs)
USGS Flow (cfs)
Model Stage (ft)
USGS Stage (ft)
Discharge (cfs)
Elevation (ft)
Time
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
910
905
900
895
890
885
880
875
3/15/09
3/20/09
3/25/09
3/30/09
4/4/09
4/9/09
4/14/09
Excellent Data is within 2% of actual flow
Good Data is within 5% of actual flow
Fair Data is within 8% of actual flow
Poor Data is > 8% of actual flow
Accepted range of values based on the USGS Discharge Measurement Quality Codes


2009 Red River at Halstad, MN
Model Flow (cfs)
USGS Flow (cfs)
Model Stage (ft)
USGS Stage (ft)
Discharge (cfs)
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Elevation (ft)
870
865
860
855
850
845
840
835
3/15/09
3/20/09
3/25/09
3/30/09
4/4/09
4/9/09
4/14/09
Time
Excellent Data is within 2% of actual flow
Good Data is within 5% of actual flow
Fair Data is within 8% of actual flow
Poor Data is > 8% of actual flow
Accepted range of values based on the USGS Discharge Measurement Quality Codes


2009 Red River at Thompson, ND
Model Flow (cfs)
USGS Flow (cfs)
Model Stage (ft)
USGS Stage (ft)
Discharge (cfs)
65,000
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Elevation (ft)
852
848
844
840
836
832
828
824
820
816
812
808
804
800
3/15/09
3/20/09
3/25/09
3/30/09
4/4/09
4/9/09
4/14/09
Time
Excellent Data is within 2% of actual flow
Good Data is within 5% of actual flow
Fair Data is within 8% of actual flow
Poor Data is > 8% of actual flow
Accepted range of values based on the USGS Discharge Measurement Quality Codes

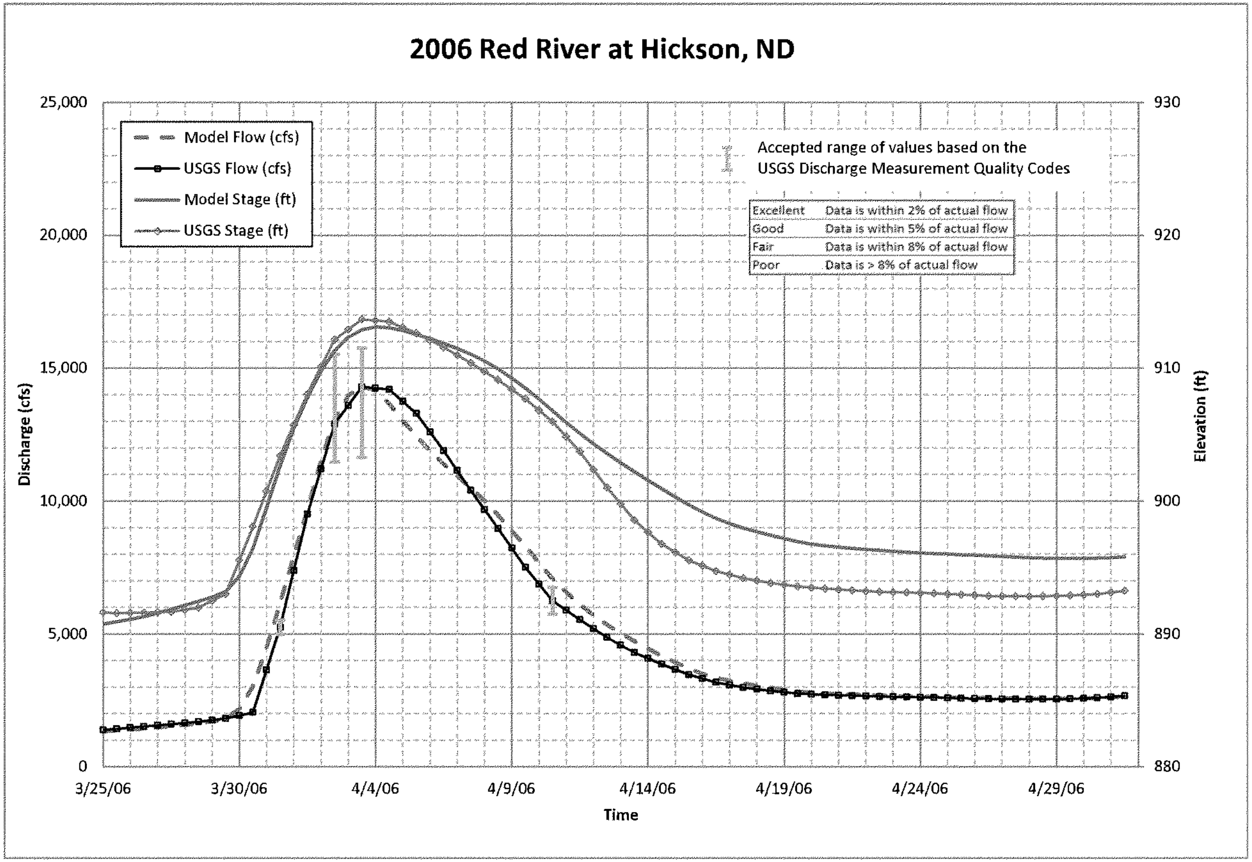

2009 Red River at Grand Forks, ND
Model Flow (cfs)
USGS Flow (cfs)
Model Stage (ft)
USGS Stage (ft)
Discharge (cfs)
Elevation (ft)
Time
0
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
790
795
800
805
810
815
820
825
830
3/15/09
3/20/09
3/25/09
3/30/09
4/4/09
4/9/09
4/14/09
Accepted range of values based on the USGS Discharge Measurement Quality Codes
Excellent Data is within 2% of actual flow
Good Data is within 5% of actual flow
Fair Data is within 8% of actual flow
Poor Data is > 8% of actual flow

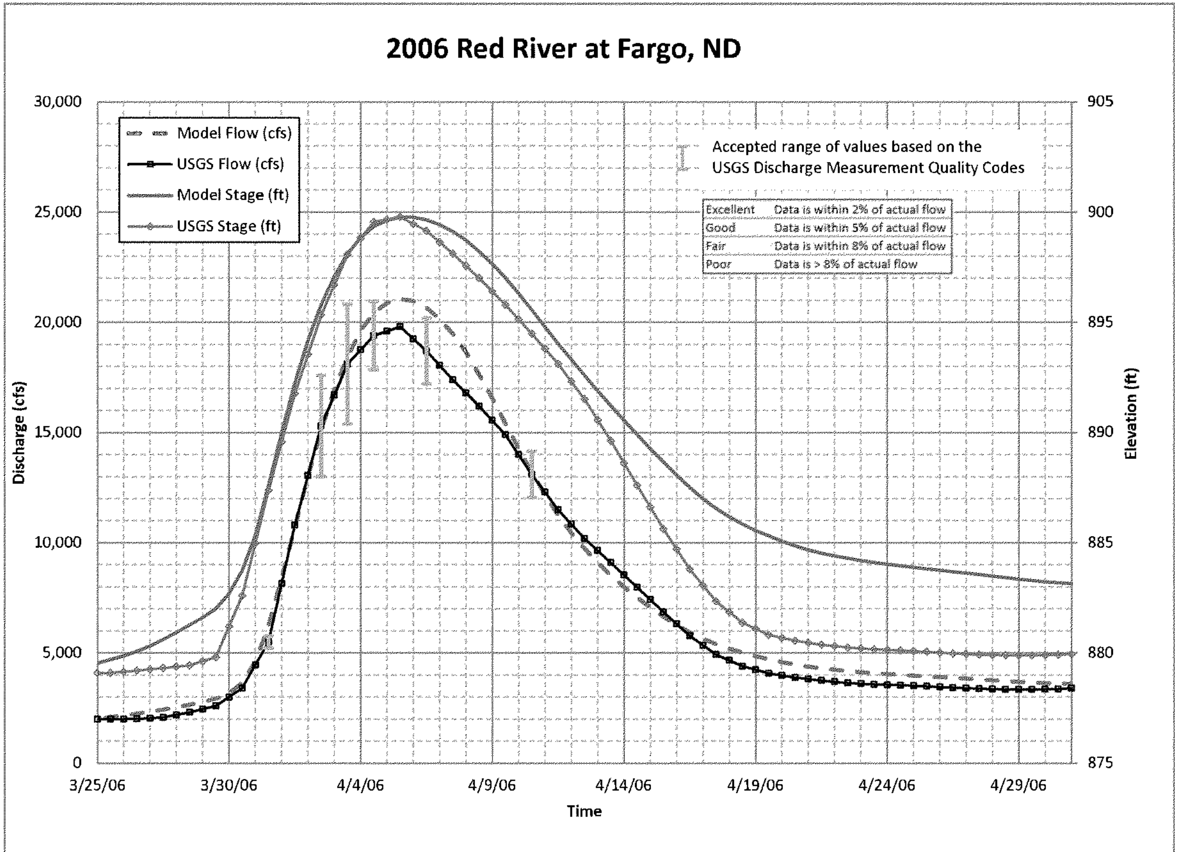

2009 Red River at Drayton, ND
Model Flow (cfs)
USGS Flow (cfs)
Model Stage (ft)
USGS Stage (ft)
Discharge (cfs)
Elevation (ft)
Time
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
804
800
796
792
788
784
780
776
772
768
764
3/15/09
3/20/09
3/25/09
3/30/09
4/4/09
4/9/09
4/14/09
Excellent Data is within 2% of actual flow
Good Data is within 5% of actual flow
Fair Data is within 8% of actual flow
Poor Data is > 8% of actual flow
Accepted range of values based on the USGS Discharge Measurement Quality Codes

Appendix B – Hydraulics
Existing Condition

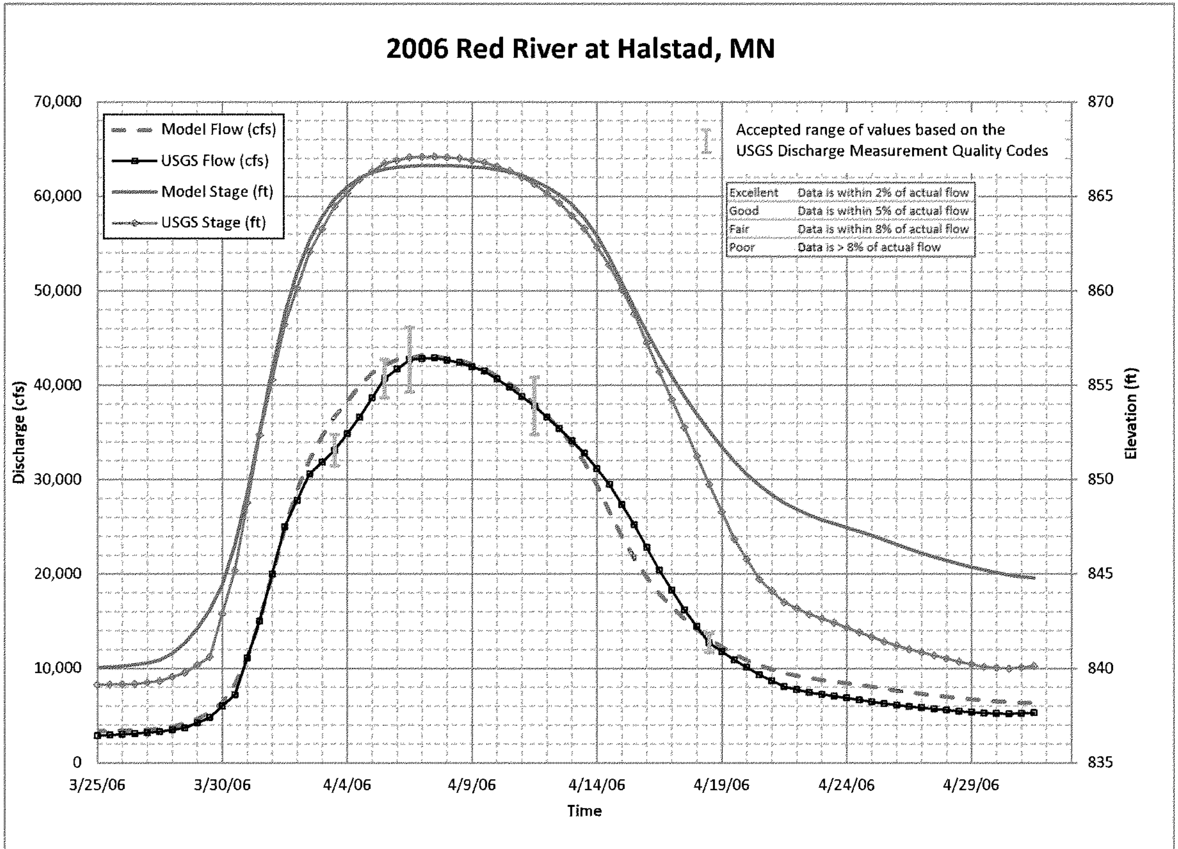
Exhibit B

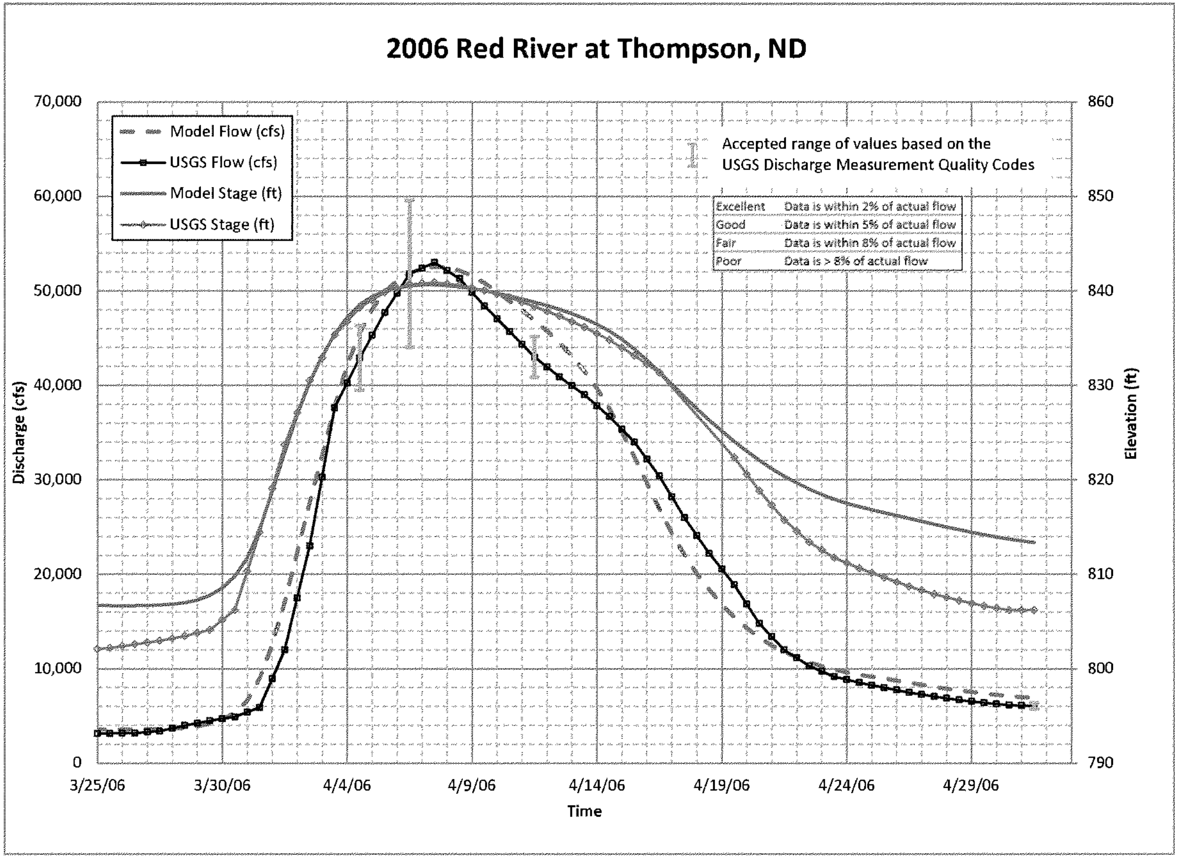
2006 Flood Verification Discharge Hydrographs

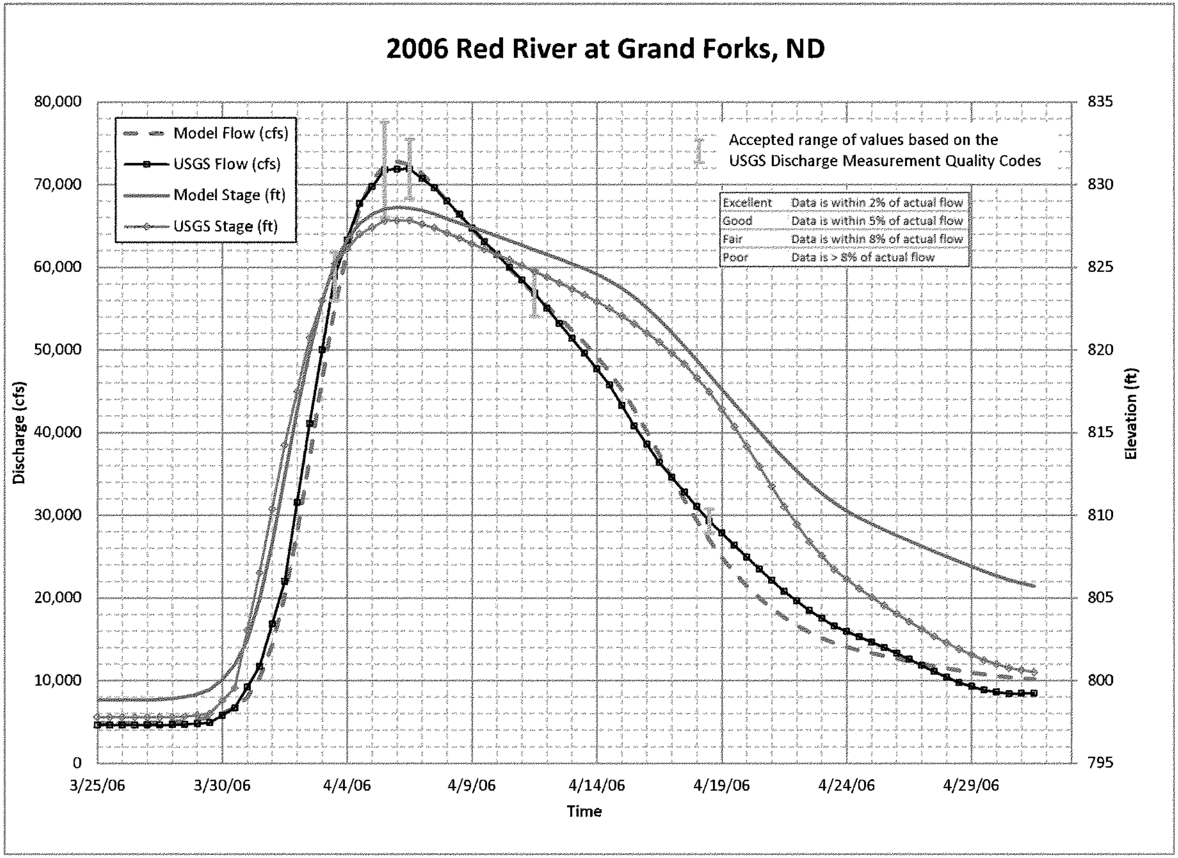

2006 Red River at Hickson, ND
Model Flow (cfs)
USGS Flow (cfs)
Model Stage (ft)
USGS Stage (ft)
Accepted range of values based on the
USGS Discharge Measurement Quality Codes
Excellent Data is within 2% of actual flow
Good Data is within 5% of actual flow
Fair Data is within 8% of actual flow
Poor Data is > 8% of actual flow
Discharge (cfs)
25,000
20,000
15,000
10,000
5,000
0
Elevation (ft)
930
920
910
900
890
880
3/25/06
3/30/06
4/4/06
4/9/06
4/14/06
4/19/06
4/24/06
4/29/06
Time

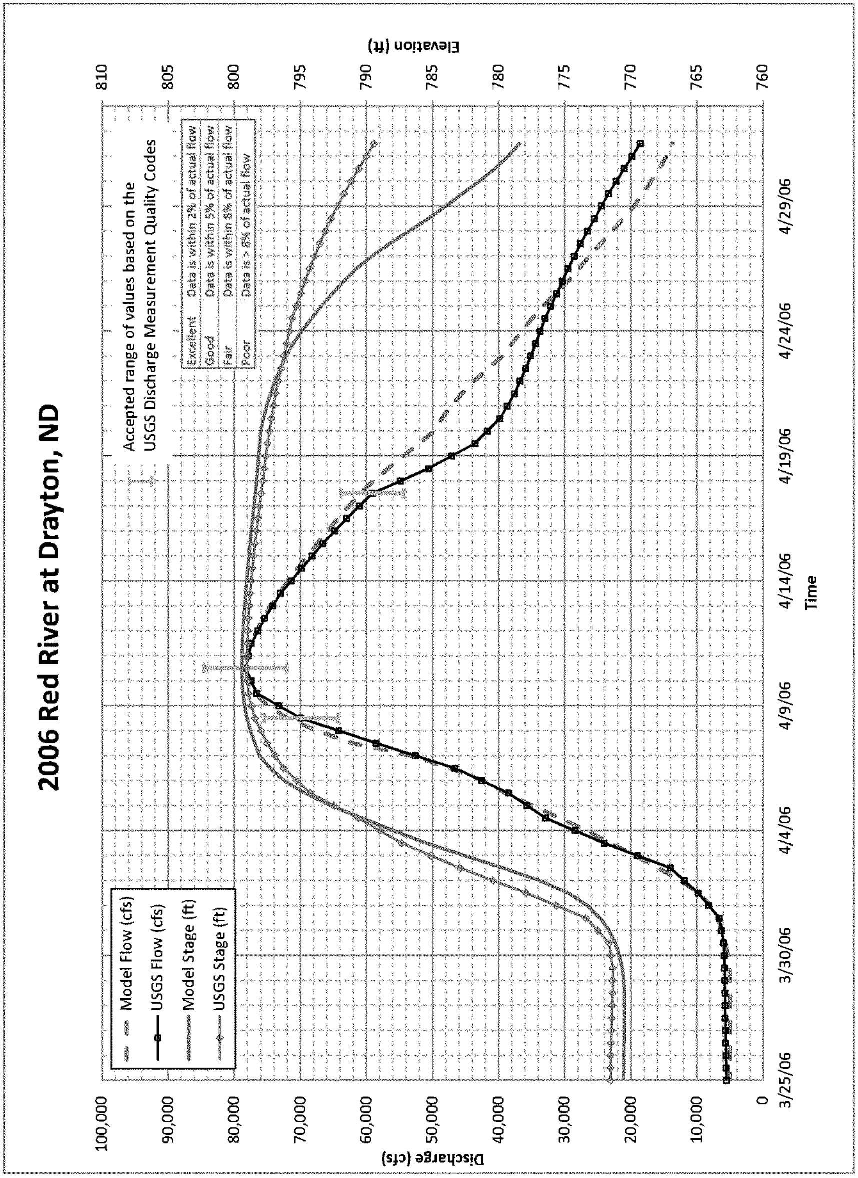


2006 Red River at Fargo, ND
Model Flow (cfs)
USGS Flow (cfs)
Model Stage (ft)
USGS Stage (ft)
Accepted range of values based on the
USGS Discharge Measurement Quality Codes
Excellent Data is within 2% of actual flow
Good Data is within 5% of actual flow
Fair Data is within 8% of actual flow
Poor Data is > 8% of actual flow
Discharge (cfs)
30,000
25,000
20,000
15,000
10,000
5,000
0
Elevation (ft)
905
900
895
890
885
880
875
3/25/06
3/30/06
4/4/06
4/9/06
4/14/06
4/19/06
4/24/06
4/29/06
Time


2006 Red River at Halstad, MN
Model Flow (cfs)
USGS Flow (cfs)
Model Stage (ft)
USGS Stage (ft)
Accepted range of values based on the
USGS Discharge Measurement Quality Codes
Excellent Data is within 2% of actual flow
Good Data is within 5% of actual flow
Fair Data is within 8% of actual flow
Poor Data is > 8% of actual flow
Discharge (cfs)
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Elevation (ft)
870
865
860
855
850
845
840
835
3/25/06
3/30/06
4/4/06
4/9/06
4/14/06
4/19/06
4/24/06
4/29/06
Time


2006 Red River at Thompson, ND
Model Flow (cfs)
USGS Flow (cfs)
Model Stage (ft)
USGS Stage (ft)
Accepted range of values based on the
USGS Discharge Measurement Quality Codes
Excellent Data is within 2% of actual flow
Good Data is within 5% of actual flow
Fair Data is within 8% of actual flow
Poor Data is > 8% of actual flow
Discharge (cfs)
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Elevation (ft)
860
850
840
830
820
810
800
790
3/25/06
3/30/06
4/4/06
4/9/06
4/14/06
4/19/06
4/24/06
4/29/06
Time

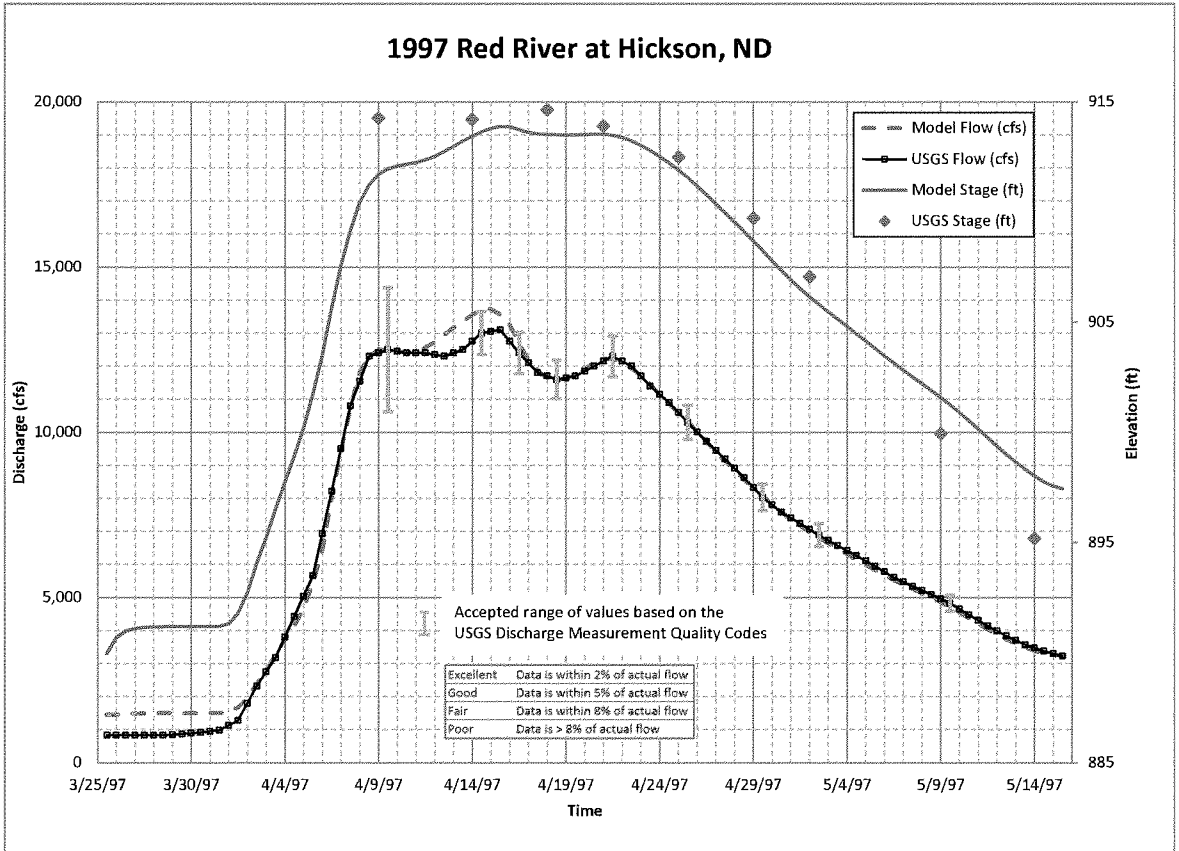

2006 Red River at Grand Forks, ND
Model Flow (cfs)
USGS Flow (cfs)
Model Stage (ft)
USGS Stage (ft)
Accepted range of values based on the
USGS Discharge Measurement Quality Codes
Excellent Data is within 2% of actual flow
Good Data is within 5% of actual flow
Fair Data is within 8% of actual flow
Poor Data is > 8% of actual flow
Discharge (cfs)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Elevation (ft)
835
830
825
820
815
810
805
800
795
3/25/06
3/30/06
4/4/06
4/9/06
4/14/06
4/19/06
4/24/06
4/29/06
Time

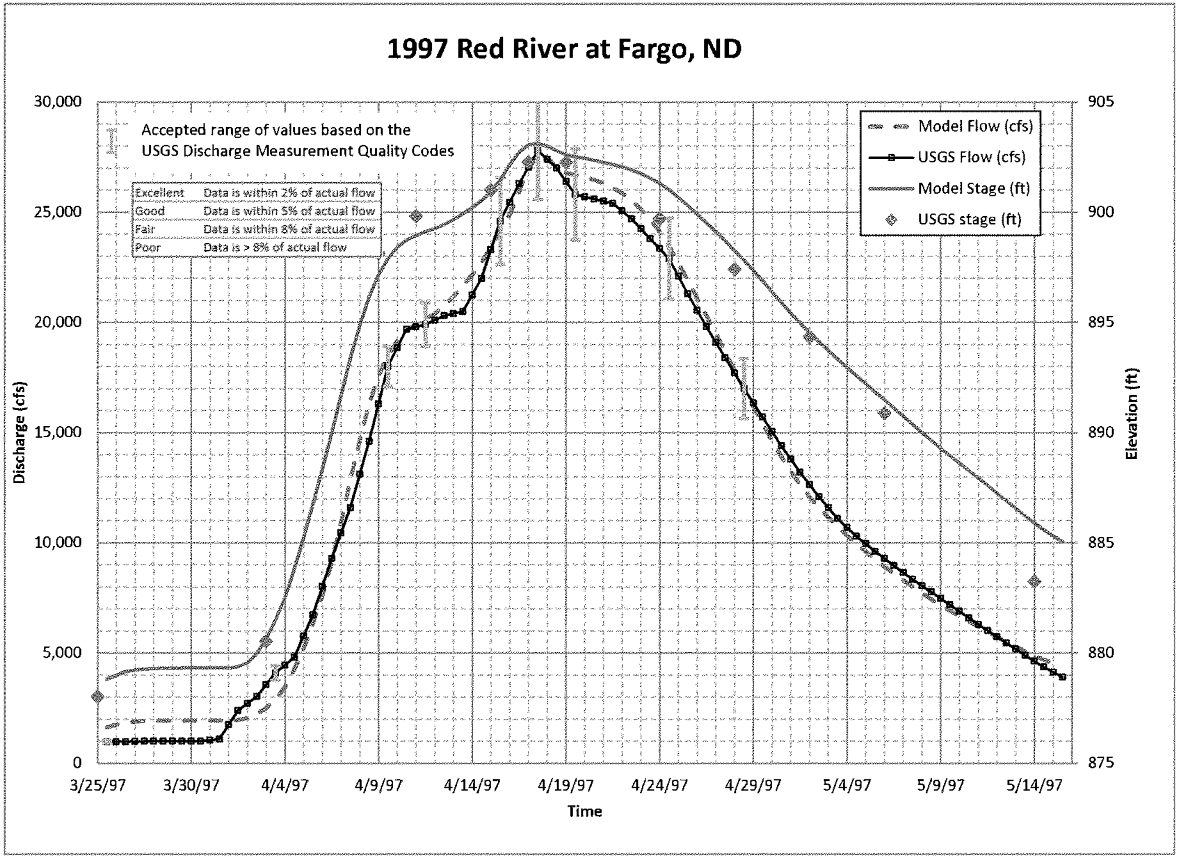

2006 Red River at Drayton, ND
Model Flow (cfs)
USGS Flow (cfs)
Model Stage (ft)
USGS Stage (ft)
Accepted range of values based on the
USGS Discharge Measurement Quality Codes
Excellent Data is within 2% of actual flow
Good Data is within 5% of actual flow
Fair Data is within 8% of actual flow
Poor Data is > 8% of actual flow
Discharge (cfs)
Elevation (ft)
Time
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
810
805
800
795
790
785
780
775
770
765
760
3/25/06
3/30/06
4/4/06
4/9/06
4/14/06
4/19/06
4/24/06
4/29/06

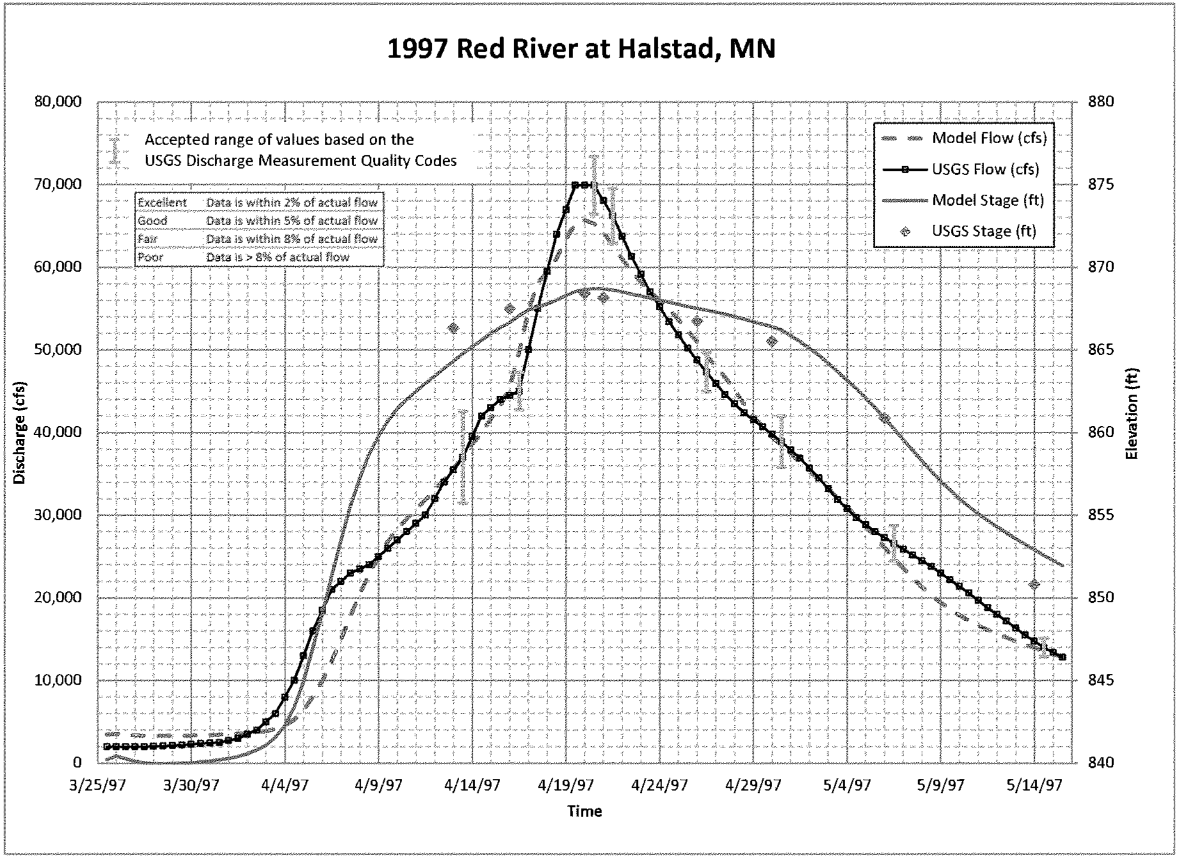
Appendix B – Hydraulics
Existing Condition

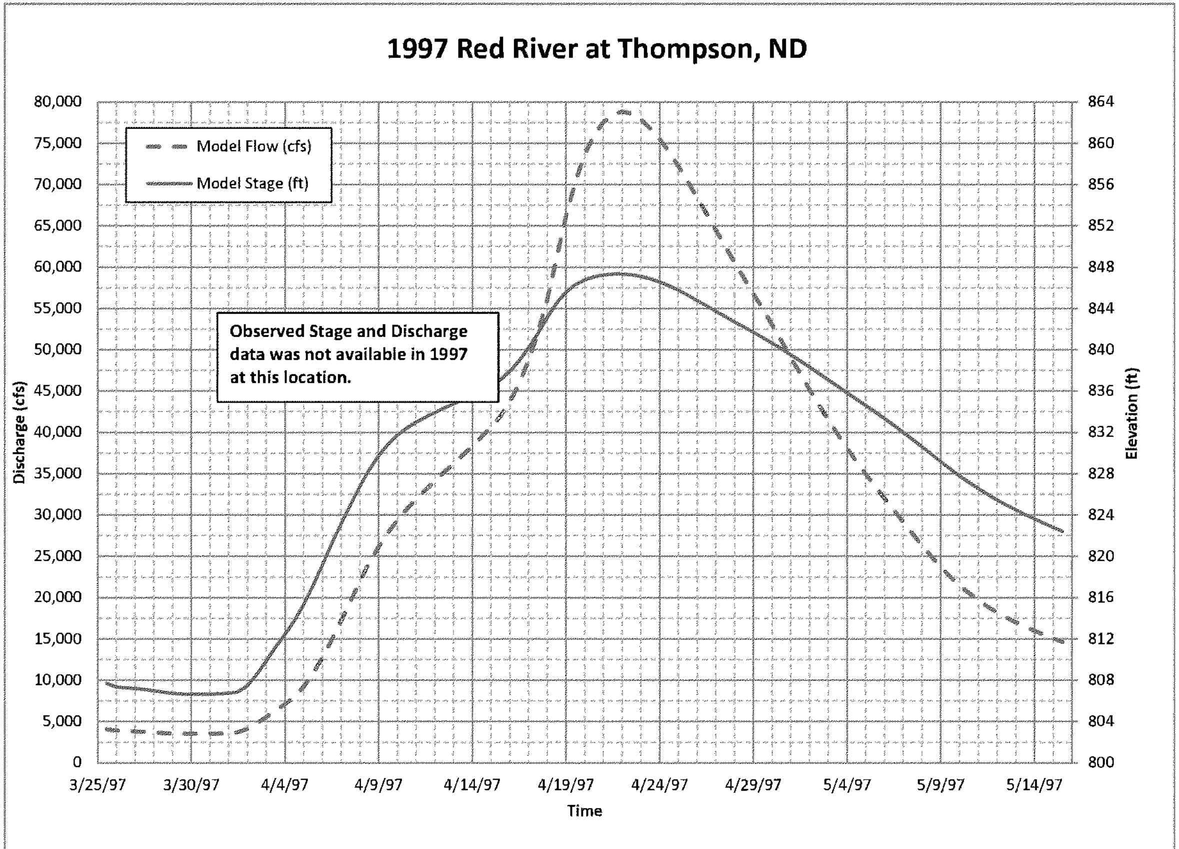
Exhibit C

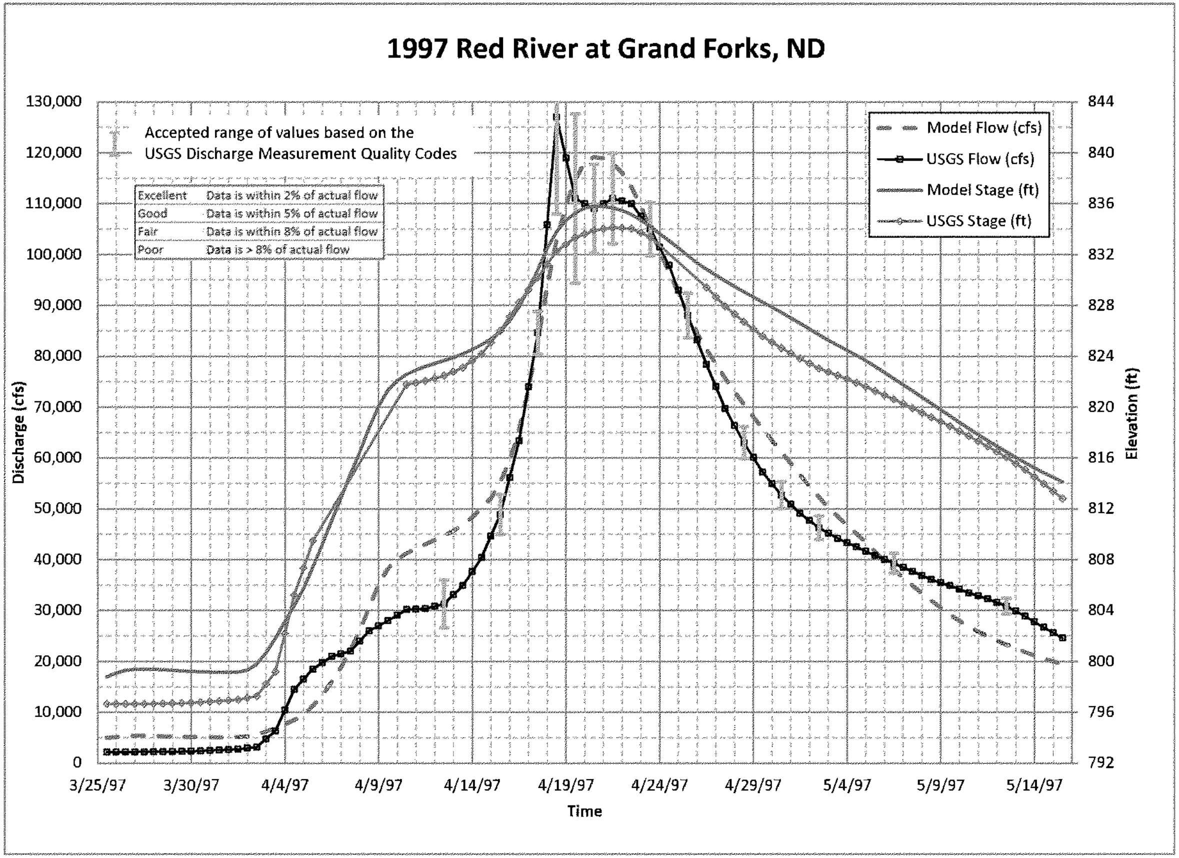
1997 Flood Verification Discharge Hydrographs

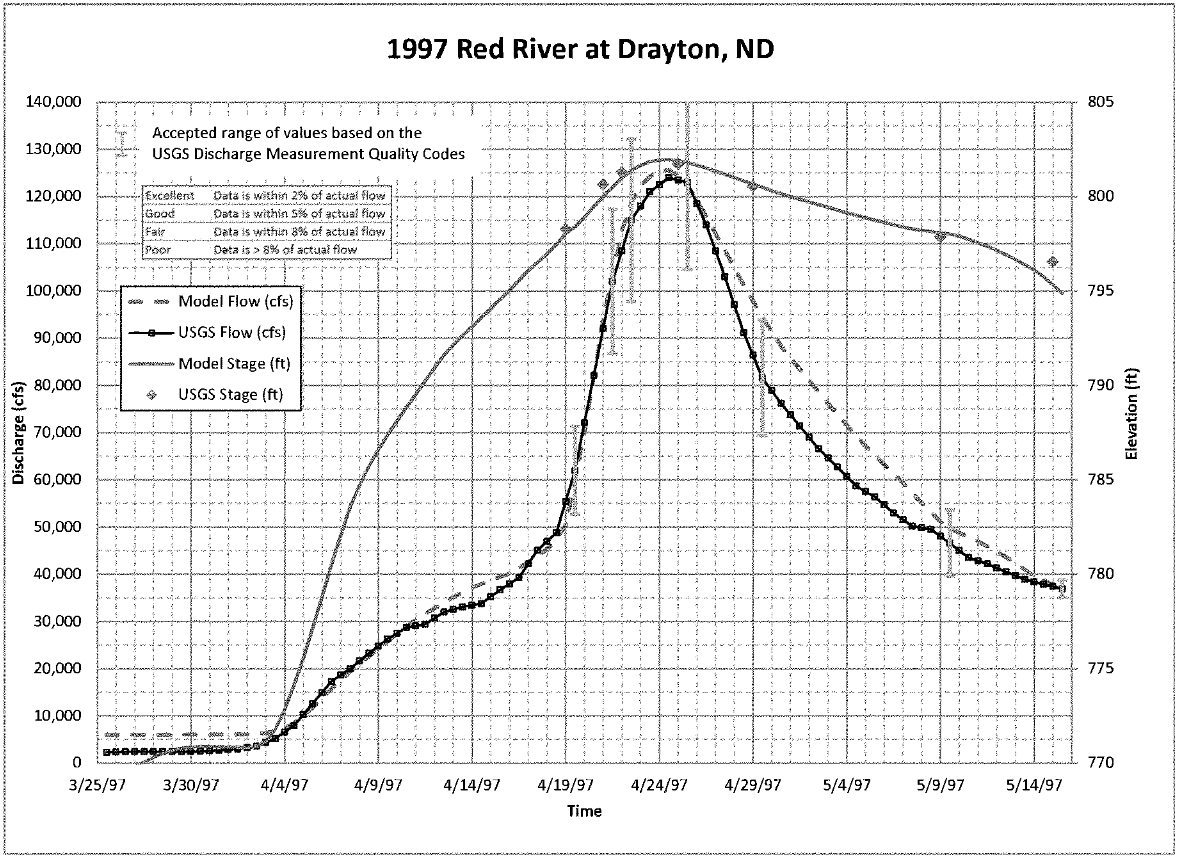

1997 Red River at Hickson, ND
Model Flow (cfs)
USGS Flow (cfs)
Model Stage (ft)
USGS Stage (ft)
Accepted range of values based on the
USGS Discharge Measurement Quality Codes
Excellent Data is within 2% of actual flow
Good Data is within 5% of actual flow
Fair Data is within 8% of actual flow
Poor Data is > 8% of actual flow
Discharge (cfs)
20,000
15,000
10,000
5,000
0
Elevation (ft)
915
905
895
885
3/25/97
3/30/97
4/4/97
4/9/97
4/14/97
4/19/97
4/24/97
4/29/97
5/4/97
5/9/97
5/14/97
Time


1997 Red River at Fargo, ND
Accepted range of values based on the
USGS Discharge Measurement Quality Codes
Excellent Data is within 2% of actual flow
Good Data is within 5% of actual flow
Fair Data is within 8% of actual flow
Poor Data is > 8% of actual flow
Model Flow (cfs)
USGS Flow (cfs)
Model Stage (ft)
USGS stage (ft)
Discharge (cfs)
30,000
25,000
20,000
15,000
10,000
5,000
0
Elevation (ft)
905
900
895
890
885
880
875
3/25/97
3/30/97
4/4/97
4/9/97
4/14/97
4/19/97
4/24/97
4/29/97
5/4/97
5/9/97
5/14/97
Time


1997 Red River at Halstad, MN
Accepted range of values based on the
USGS Discharge Measurement Quality Codes
Excellent Data is within 2% of actual flow
Good Data is within 5% of actual flow
Fair Data is within 8% of actual flow
Poor Data is > 8% of actual flow
Model Flow (cfs)
USGS Flow (cfs)
Model Stage (ft)
USGS Stage (ft)
Discharge (cfs)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Elevation (ft)
880
875
870
865
860
855
850
845
840
3/25/97
3/30/97
4/4/97
4/9/97
4/14/97
4/19/97
4/24/97
4/29/97
5/4/97
5/9/97
5/14/97
Time


1997 Red River at Thompson, ND
Model Flow (cfs)
Model Stage (ft)
Observed Stage and Discharge data was not available in 1997 at this location.
Discharge (cfs)
80,000
75,000
70,000
65,000
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Elevation (ft)
864
860
856
852
848
844
840
836
832
828
824
820
816
812
808
804
800
3/25/97
3/30/97
4/4/97
4/9/97
4/14/97
4/19/97
4/24/97
4/29/97
5/4/97
5/9/97
5/14/97
Time

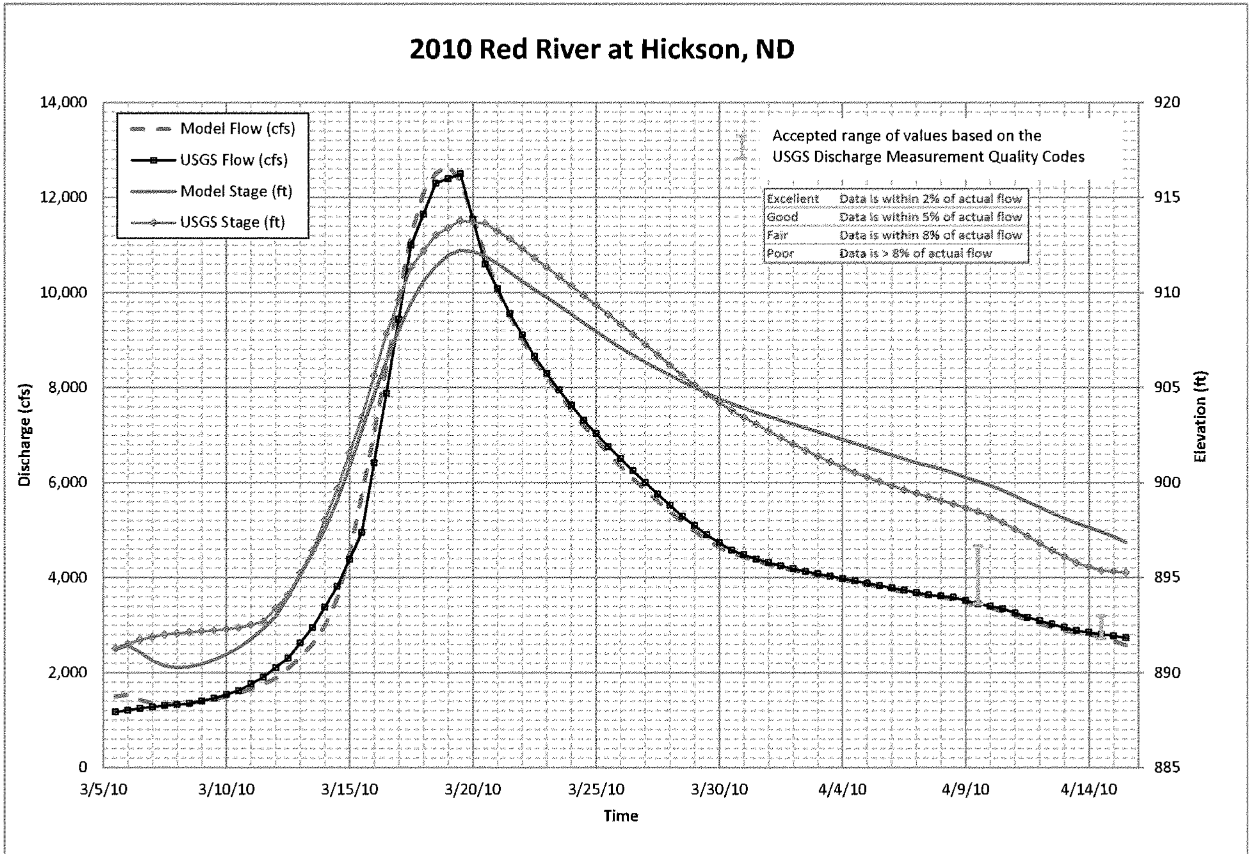

1997 Red River at Grand Forks, ND
Accepted range of values based on the
USGS Discharge Measurement Quality Codes
Excellent Data is within 2% of actual flow
Good Data is within 5% of actual flow
Fair Data is within 8% of actual flow
Poor Data is > 8% of actual flow
Model Flow (cfs)
USGS Flow (cfs)
Model Stage (ft)
USGS Stage (ft)
Discharge (cfs)
130,000
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Elevation (ft)
844
840
836
832
828
824
820
816
812
808
804
800
796
792
3/25/97
3/30/97
4/4/97
4/9/97
4/14/97
4/19/97
4/24/97
4/29/97
5/4/97
5/9/97
5/14/97
Time


1997 Red River at Drayton, ND
Accepted range of values based on the
USGS Discharge Measurement Quality Codes
Excellent Data is within 2% of actual flow
Good Data is within 5% of actual flow
Fair Data is within 8% of actual flow
Poor Data is > 8% of actual flow
Model Flow (cfs)
USGS Flow (cfs)
Model Stage (ft)
USGS Stage (ft)
Discharge (cfs)
140,000
130,000
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Elevation (ft)
805
800
795
790
785
780
775
770
3/25/97
3/30/97
4/4/97
4/9/97
4/14/97
4/19/97
4/24/97
4/29/97
5/4/97
5/9/97
5/14/97
Time

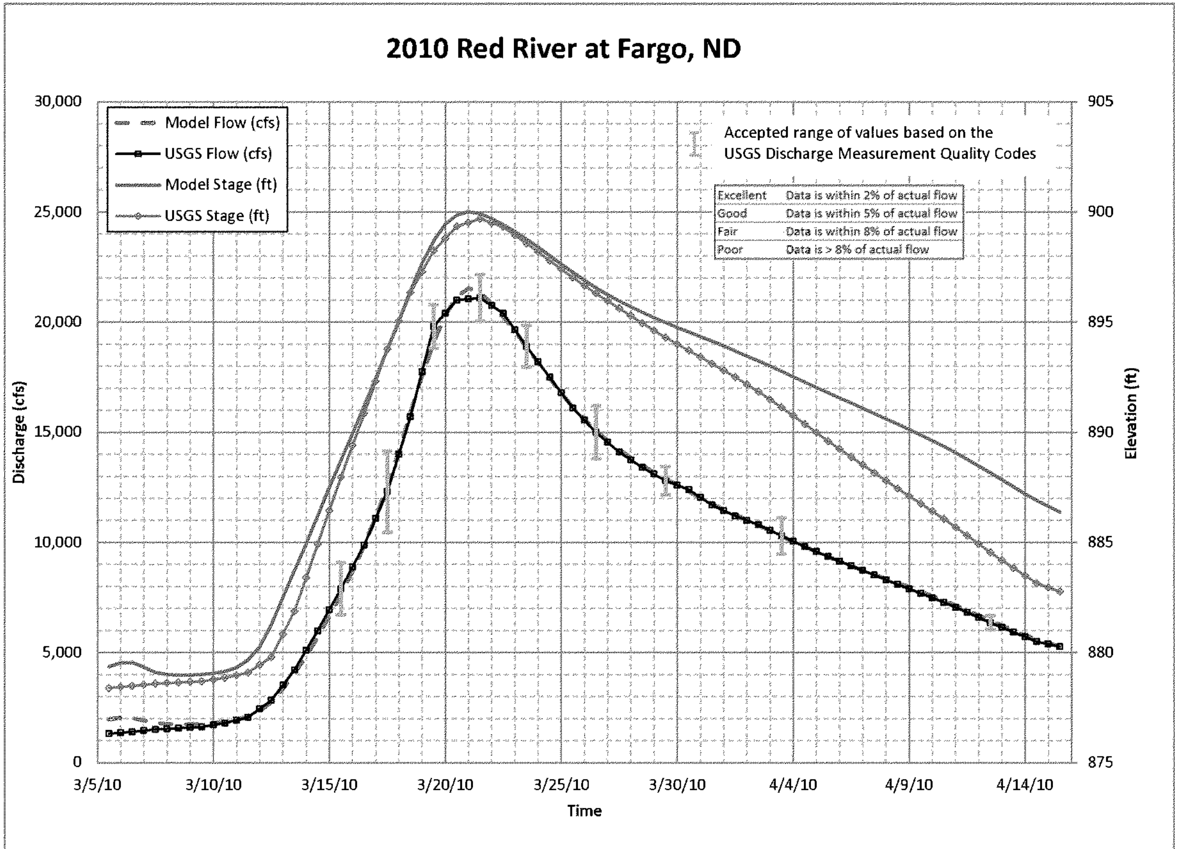
Appendix B – Hydraulics
Existing Condition

Exhibit D

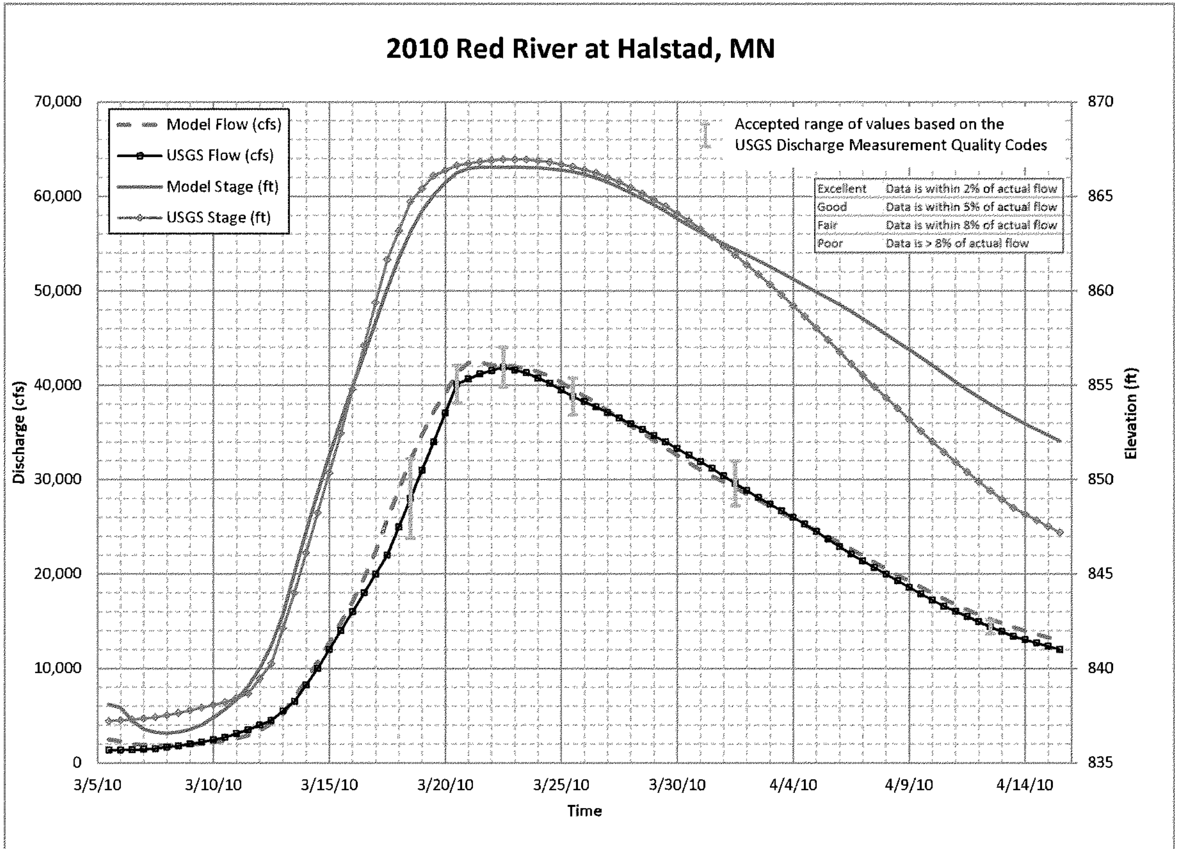
2010 Flood Verification Discharge Hydrographs

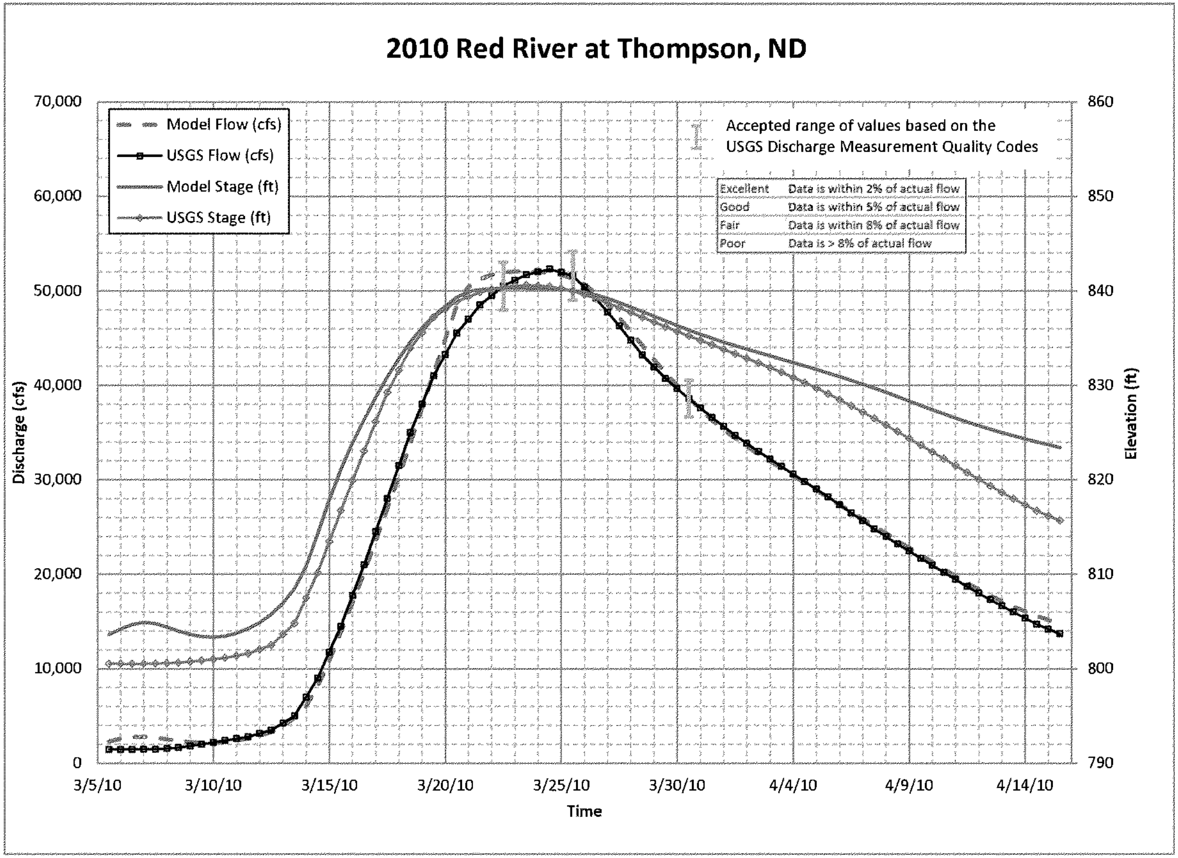


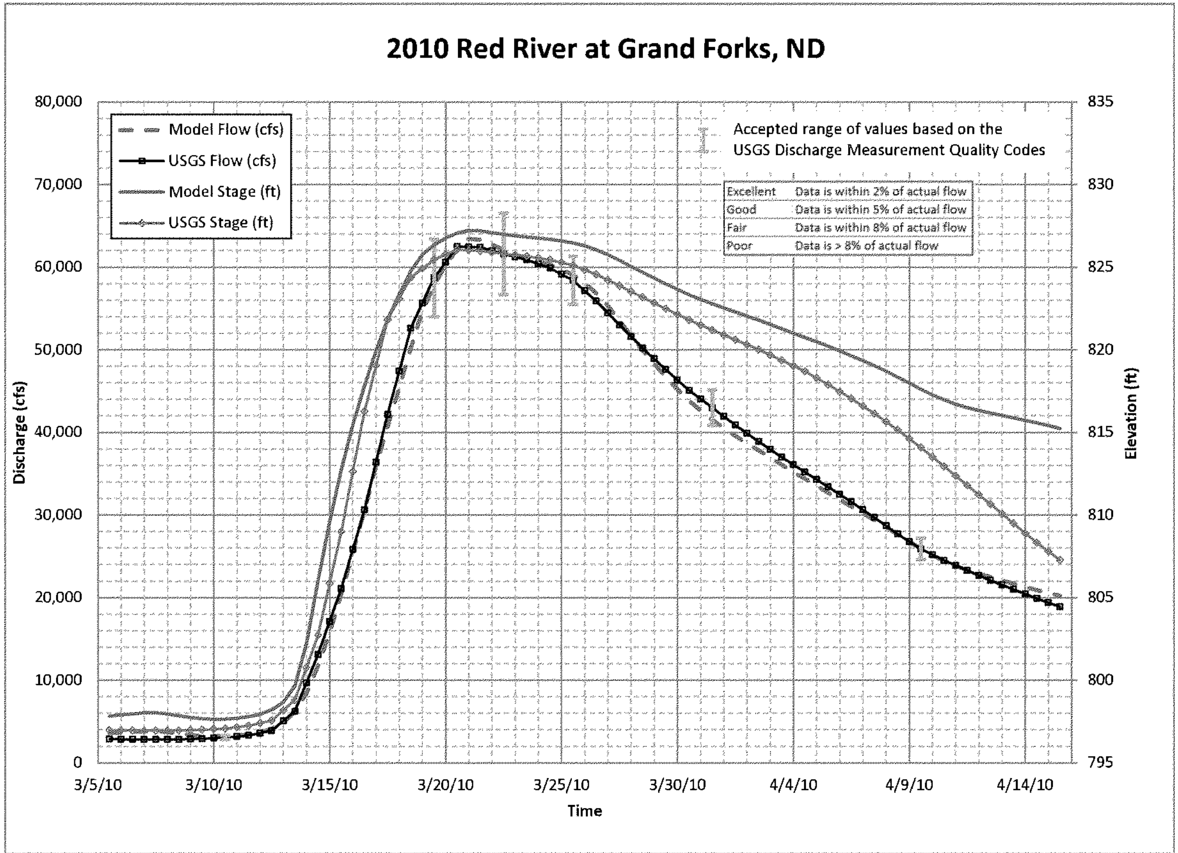
2010 Red River at Hickson, ND
Model Flow (cfs)
USGS Flow (cfs)
Model Stage (ft)
USGS Stage (ft)
Accepted range of values based on the
USGS Discharge Measurement Quality Codes
Excellent Data is within 2% of actual flow
Good Data is within 5% of actual flow
Fair Data is within 8% of actual flow
Poor Data is > 8% of actual flow
Discharge (cfs)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Elevation (ft)
920
915
910
905
900
895
890
885
3/5/10
3/10/10
3/15/10
3/20/10
3/25/10
3/30/10
4/4/10
4/9/10
4/14/10
Time



2010 Red River at Fargo, ND
Model Flow (cfs)
USGS Flow (cfs)
Model Stage (ft)
USGS Stage (ft)
Accepted range of values based on the
USGS Discharge Measurement Quality Codes
Excellent Data is within 2% of actual flow
Good Data is within 5% of actual flow
Fair Data is within 8% of actual flow
Poor Data is > 8% of actual flow
Discharge (cfs)
30,000
25,000
20,000
15,000
10,000
5,000
0
Elevation (ft)
905
900
895
890
885
880
875
3/5/10
3/10/10
3/15/10
3/20/10
3/25/10
3/30/10
4/4/10
4/9/10
4/14/10
Time


2010 Red River at Halstad, MN
Model Flow (cfs)
USGS Flow (cfs)
Model Stage (ft)
USGS Stage (ft)
Accepted range of values based on the
USGS Discharge Measurement Quality Codes
Excellent Data is within 2% of actual flow
Good Data is within 5% of actual flow
Fair Data is within 8% of actual flow
Poor Data is > 8% of actual flow
Discharge (cfs)
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Elevation (ft)
870
865
860
855
850
845
840
835
3/5/10
3/10/10
3/15/10
3/20/10
3/25/10
3/30/10
4/4/10
4/9/10
4/14/10
Time


2010 Red River at Thompson, ND
Model Flow (cfs)
USGS Flow (cfs)
Model Stage (ft)
USGS Stage (ft)
Accepted range of values based on the
USGS Discharge Measurement Quality Codes
Excellent Data is within 2% of actual flow
Good Data is within 5% of actual flow
Fair Data is within 8% of actual flow
Poor Data is > 8% of actual flow
Discharge (cfs)
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Elevation (ft)
860
850
840
830
820
810
800
790
3/5/10
3/10/10
3/15/10
3/20/10
3/25/10
3/30/10
4/4/10
4/9/10
4/14/10
Time



2010 Red River at Grand Forks, ND
Model Flow (cfs)
USGS Flow (cfs)
Model Stage (ft)
USGS Stage (ft)
Accepted range of values based on the
USGS Discharge Measurement Quality Codes
Excellent Data is within 2% of actual flow
Good Data is within 5% of actual flow
Fair Data is within 8% of actual flow
Poor Data is > 8% of actual flow
Discharge (cfs)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Elevation (ft)
835
830
825
820
815
810
805
800
795
3/5/10
3/10/10
3/15/10
3/20/10
3/25/10
3/30/10
4/4/10
4/9/10
4/14/10
Time

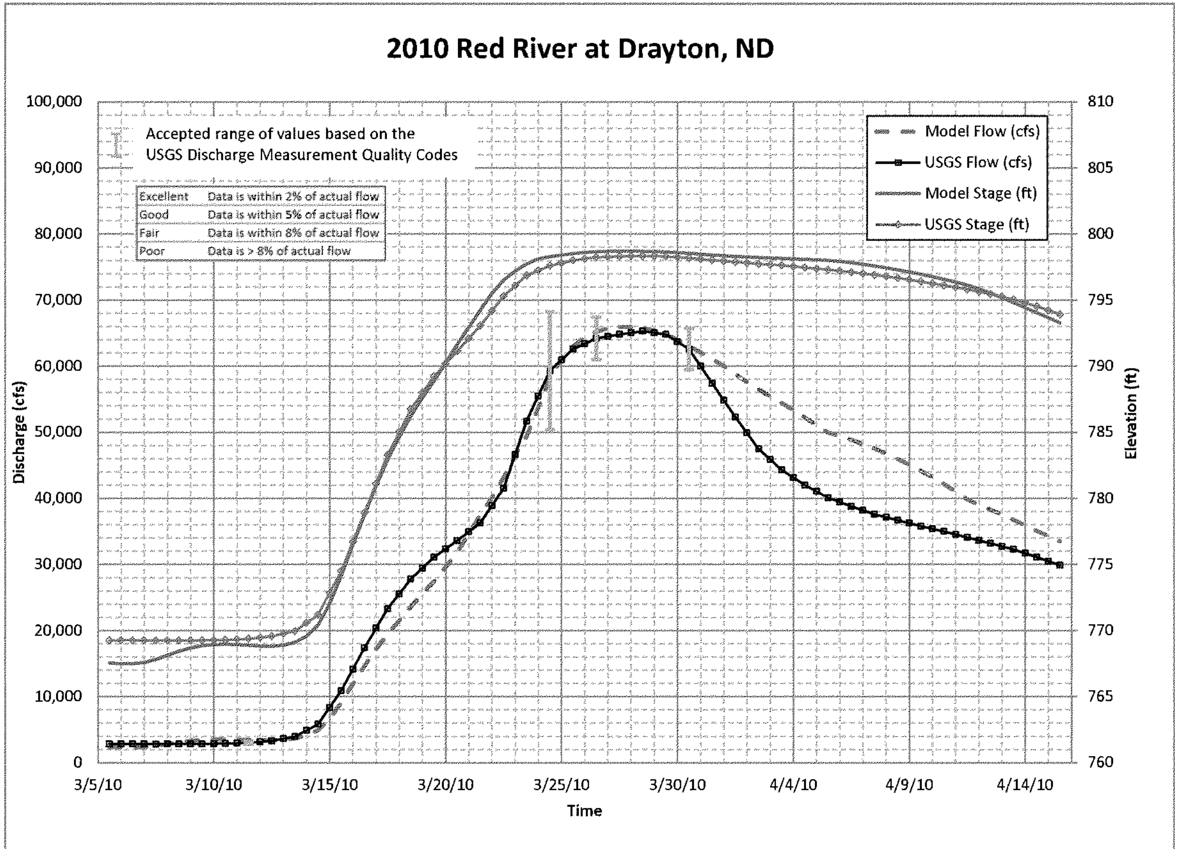
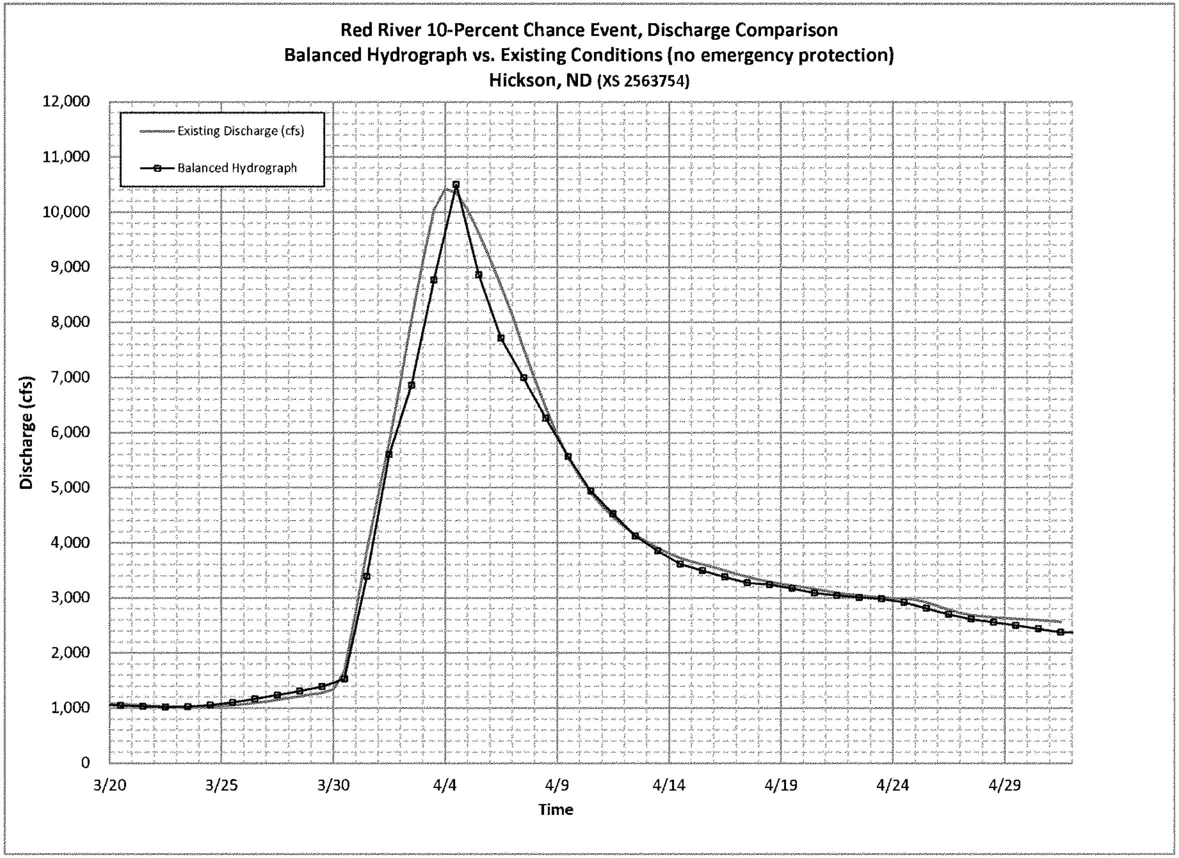
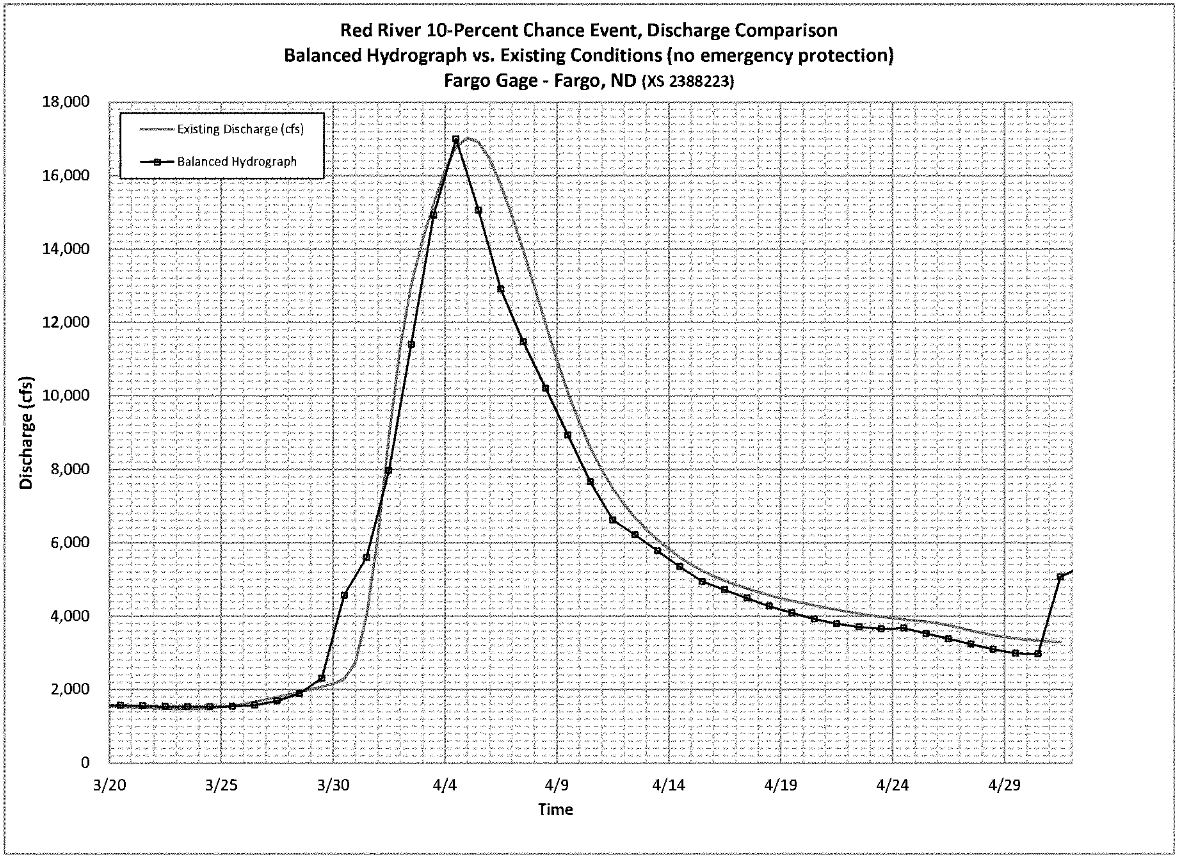
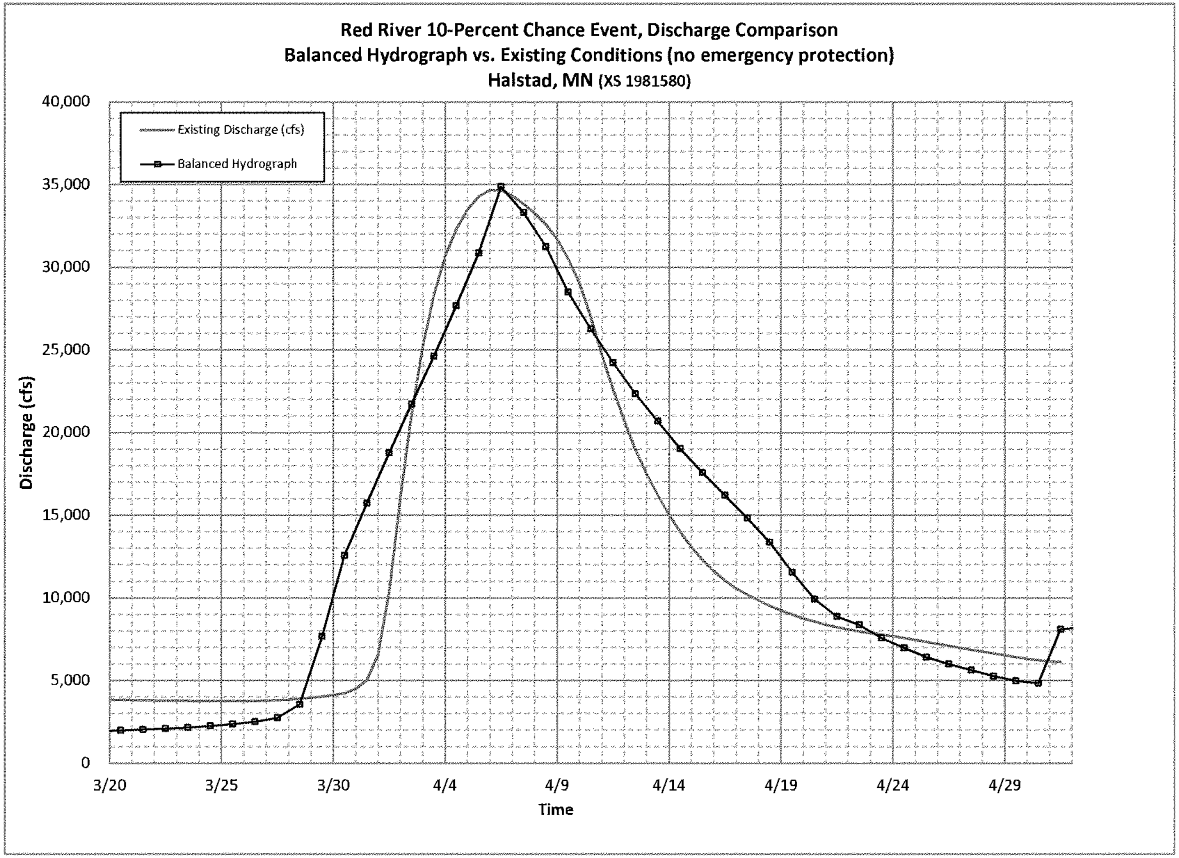

2010 Red River at Drayton, ND
Accepted range of values based on the
USGS Discharge Measurement Quality Codes
Excellent Data is within 2% of actual flow
Good Data is within 5% of actual flow
Fair Data is within 8% of actual flow
Poor Data is > 8% of actual flow
Model Flow (cfs)
USGS Flow (cfs)
Model Stage (ft)
USGS Stage (ft)
Discharge (cfs)
Elevation (ft)
Time
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
810
805
800
795
790
785
780
775
770
765
760
3/5/10
3/10/10
3/15/10
3/20/10
3/25/10
3/30/10
4/4/10
4/9/10
4/14/10

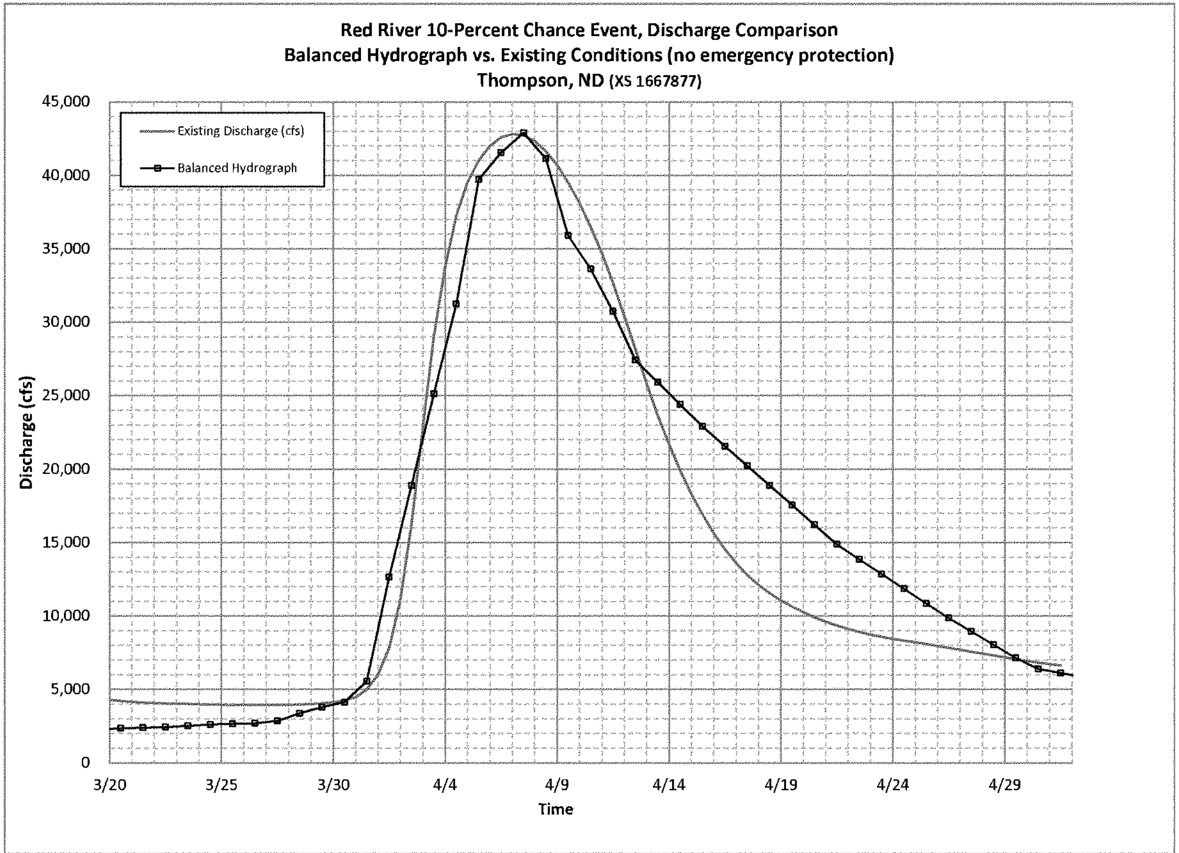
Exhibit E

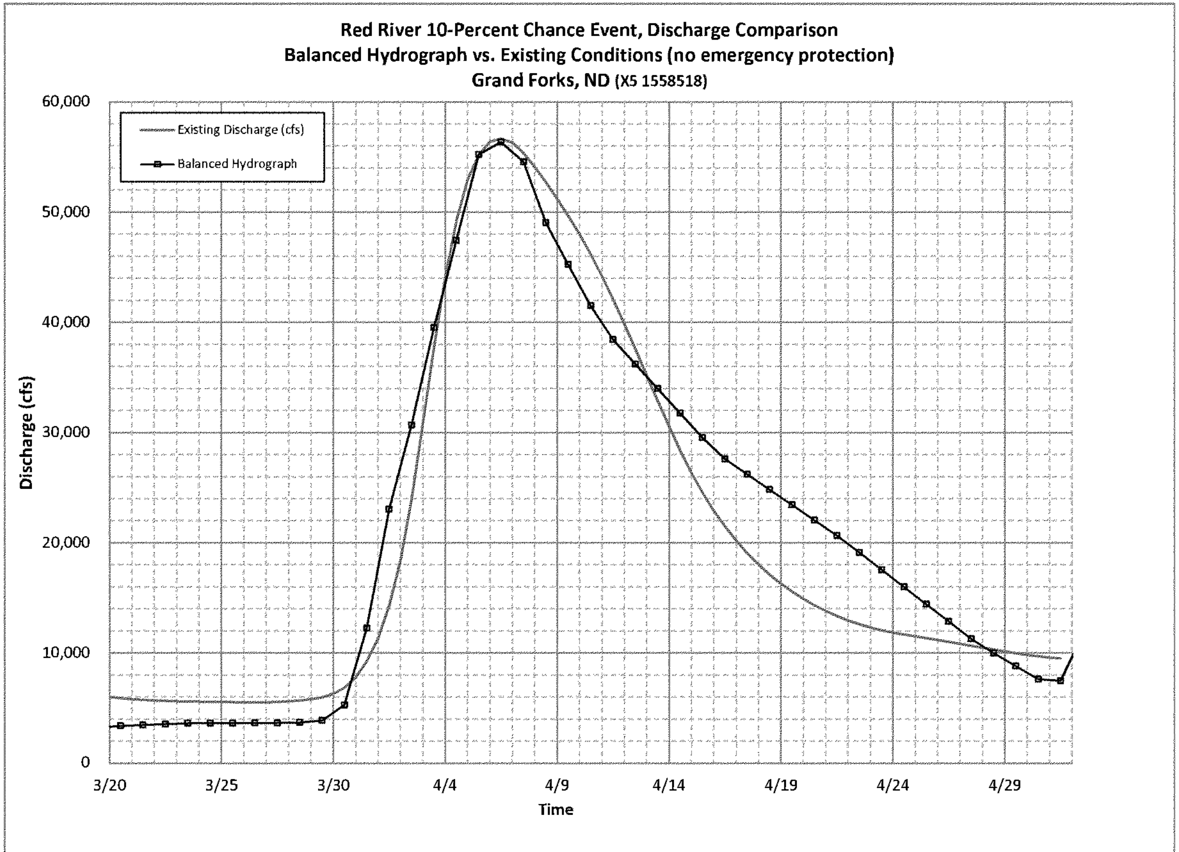
Existing Conditions 10-, 2-, 1-, and 0.2-Percent Chance Hydrographs


Red River 10-Percent Chance Event, Discharge Comparison
Balanced Hydrograph vs. Existing Conditions (no emergency protection)
Hickson, ND (XS 2563754)
Existing Discharge (cfs)
Balanced Hydrograph
Discharge (cfs)
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

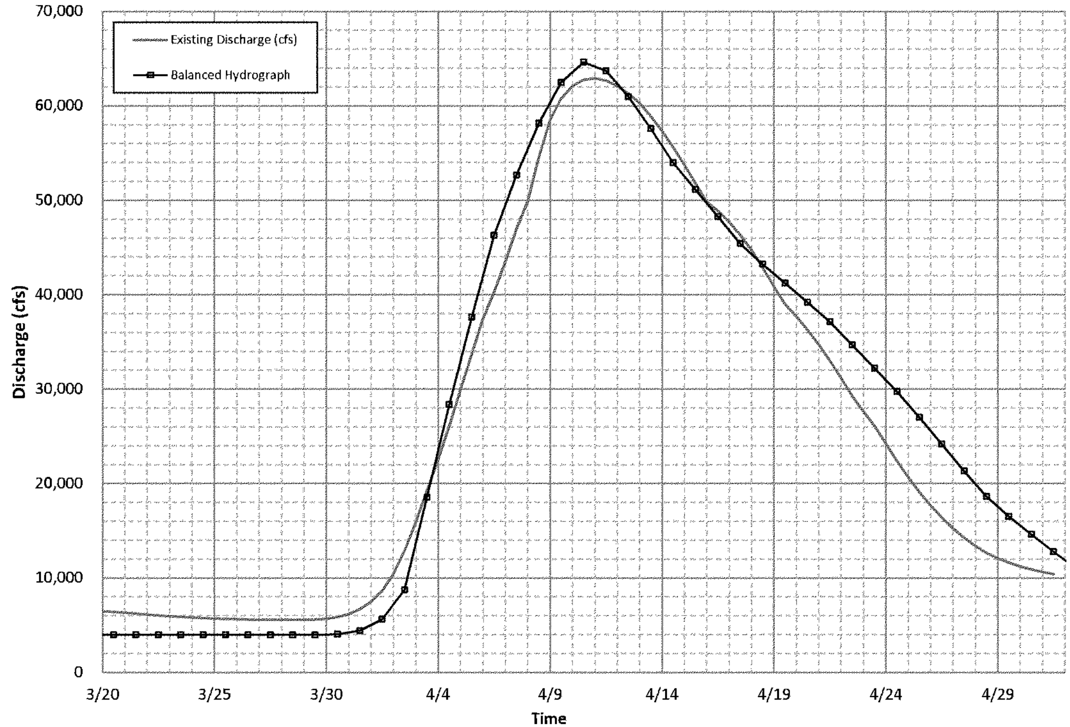

Red River 10-Percent Chance Event, Discharge Comparison
Balanced Hydrograph vs. Existing Conditions (no emergency protection)
Fargo Gage - Fargo, ND (XS 2388223)
Existing Discharge (cfs)
Balanced Hydrograph
Discharge (cfs)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

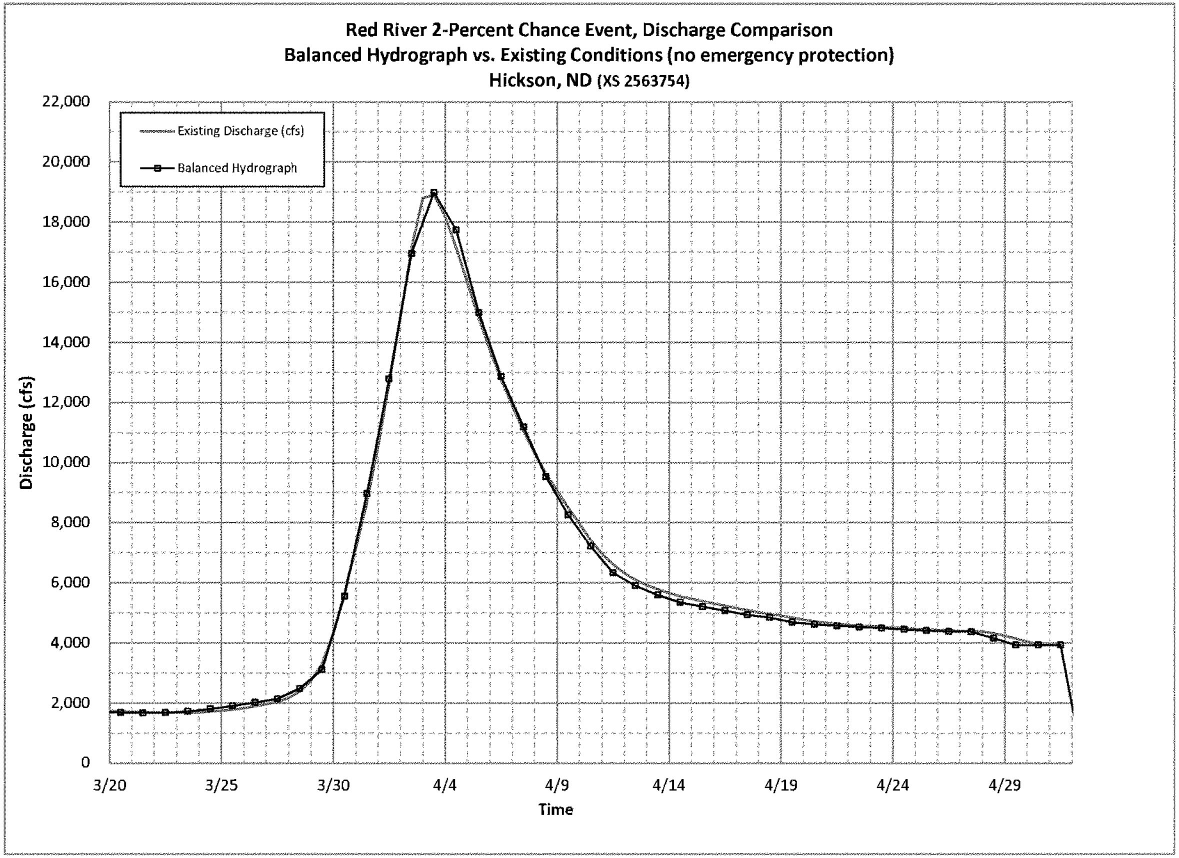

Red River 10-Percent Chance Event, Discharge Comparison
Balanced Hydrograph vs. Existing Conditions (no emergency protection)
Halstad, MN (XS 1981580)
Existing Discharge (cfs)
Balanced Hydrograph
Discharge (cfs)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

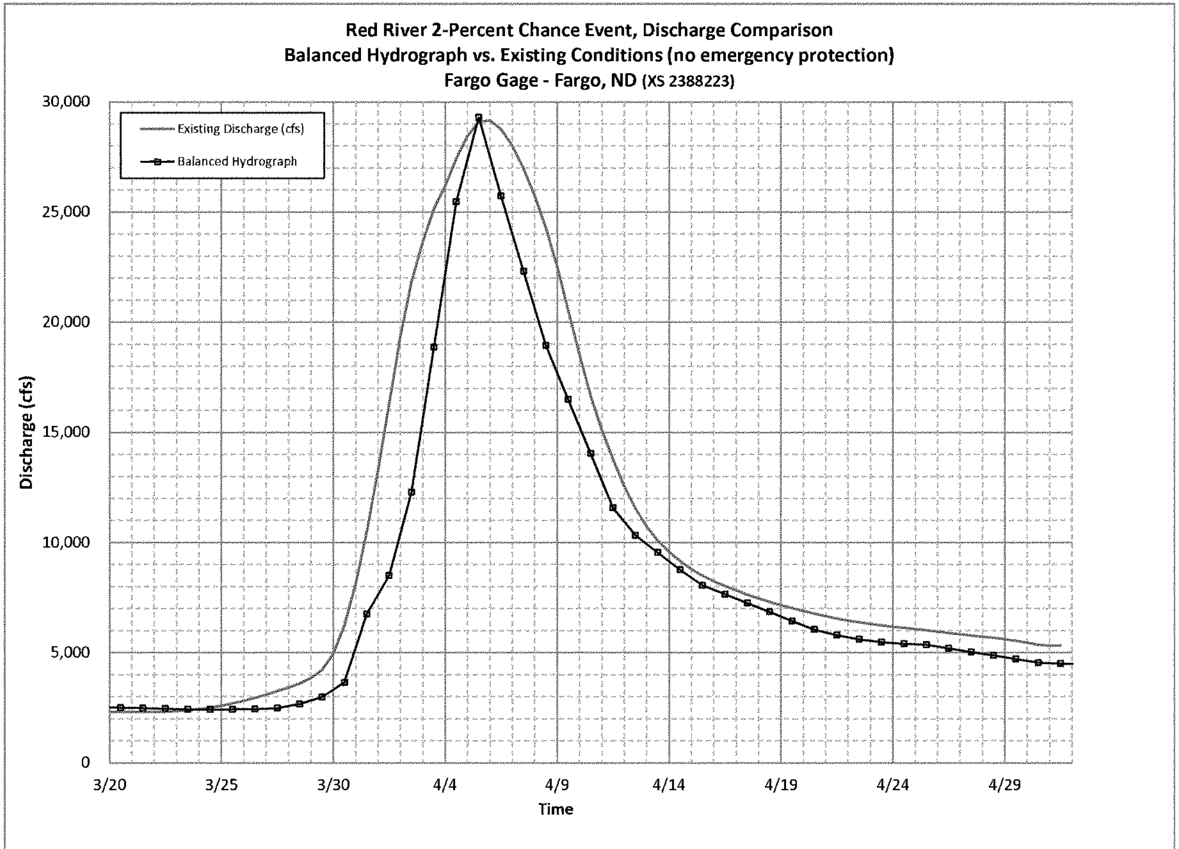

Red River 10-Percent Chance Event, Discharge Comparison
Balanced Hydrograph vs. Existing Conditions (no emergency protection)
Thompson, ND (XS 1667877)
Existing Discharge (cfs)
Balanced Hydrograph
Discharge (cfs)
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

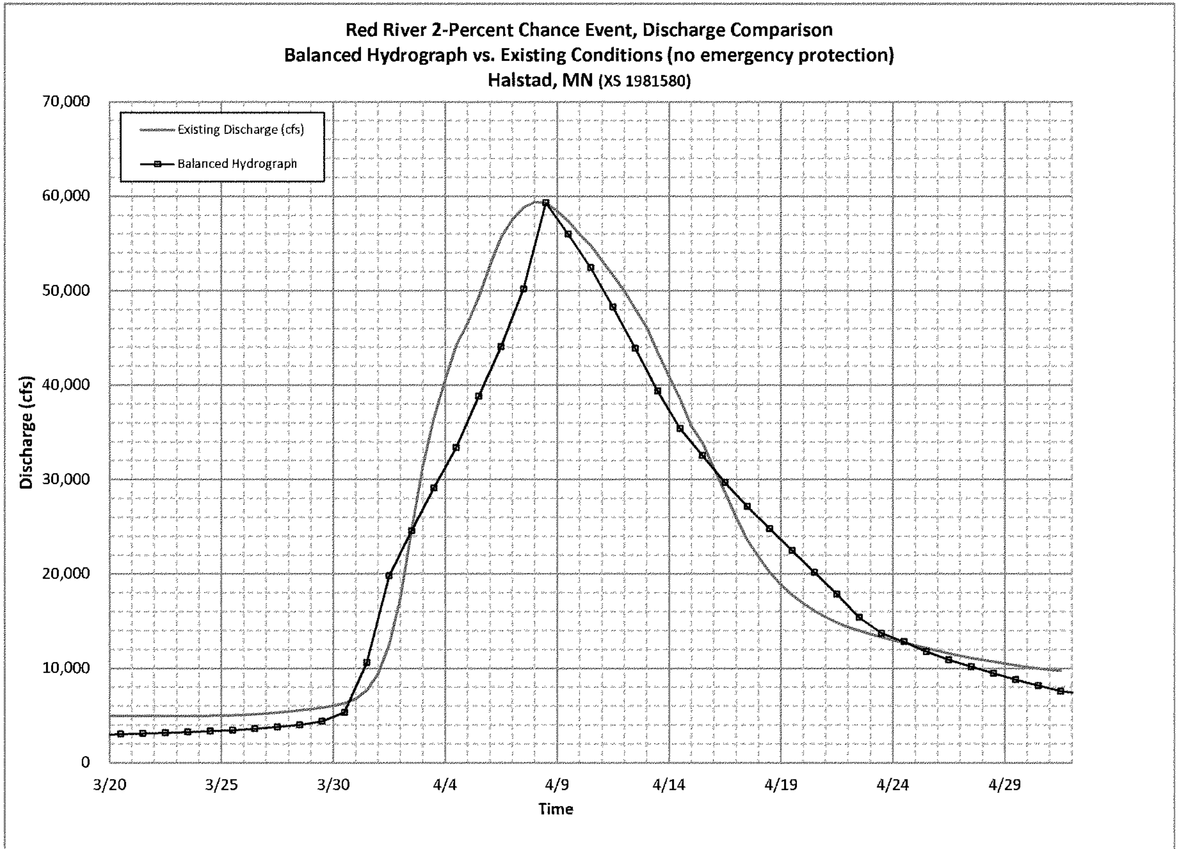

Red River 10-Percent Chance Event, Discharge Comparison
Balanced Hydrograph vs. Existing Conditions (no emergency protection)
Grand Forks, ND (X5 1558518)
Existing Discharge (cfs)
Balanced Hydrograph
Discharge (cfs)
60,000
50,000
40,000
30,000
20,000
10,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

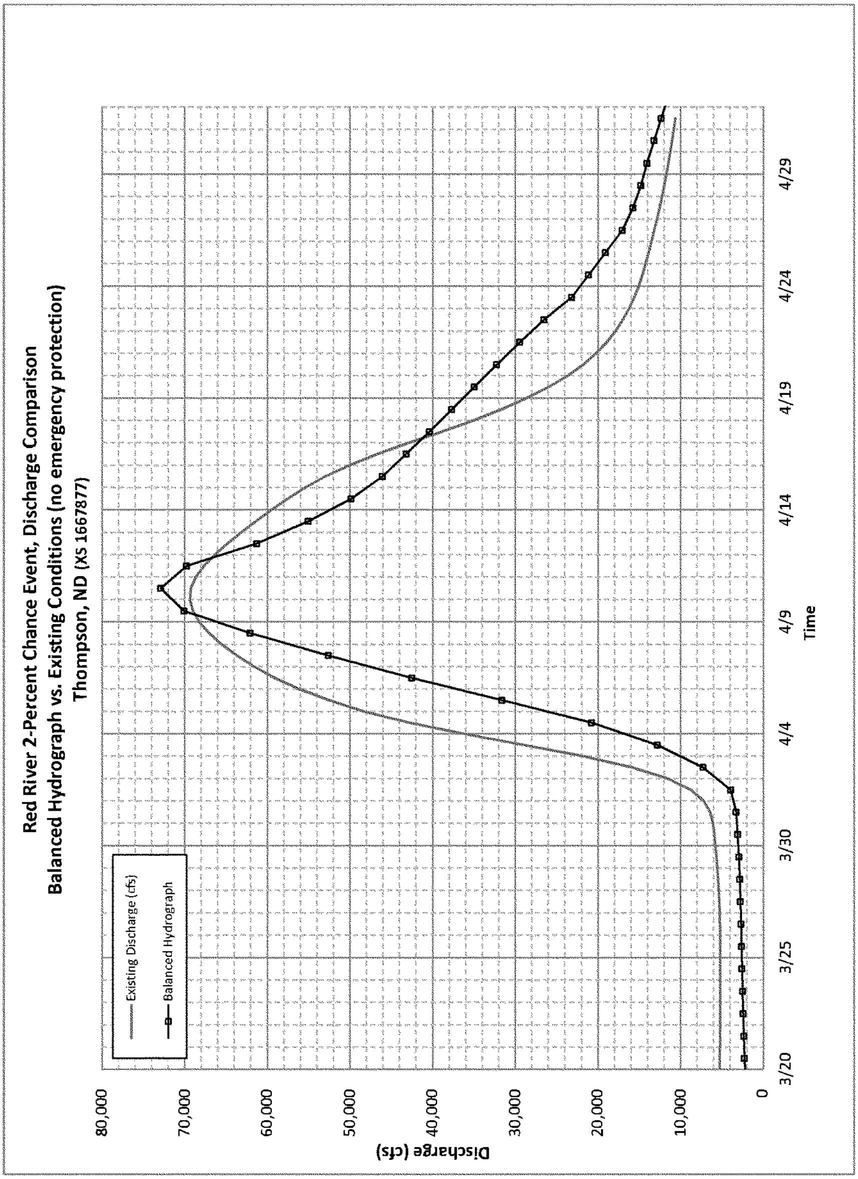
Red River 10-Percent Chance Event, Discharge Comparison
Balanced Hydrograph vs. Existing Conditions (no emergency protection)
Drayton, ND (XS 1062362)

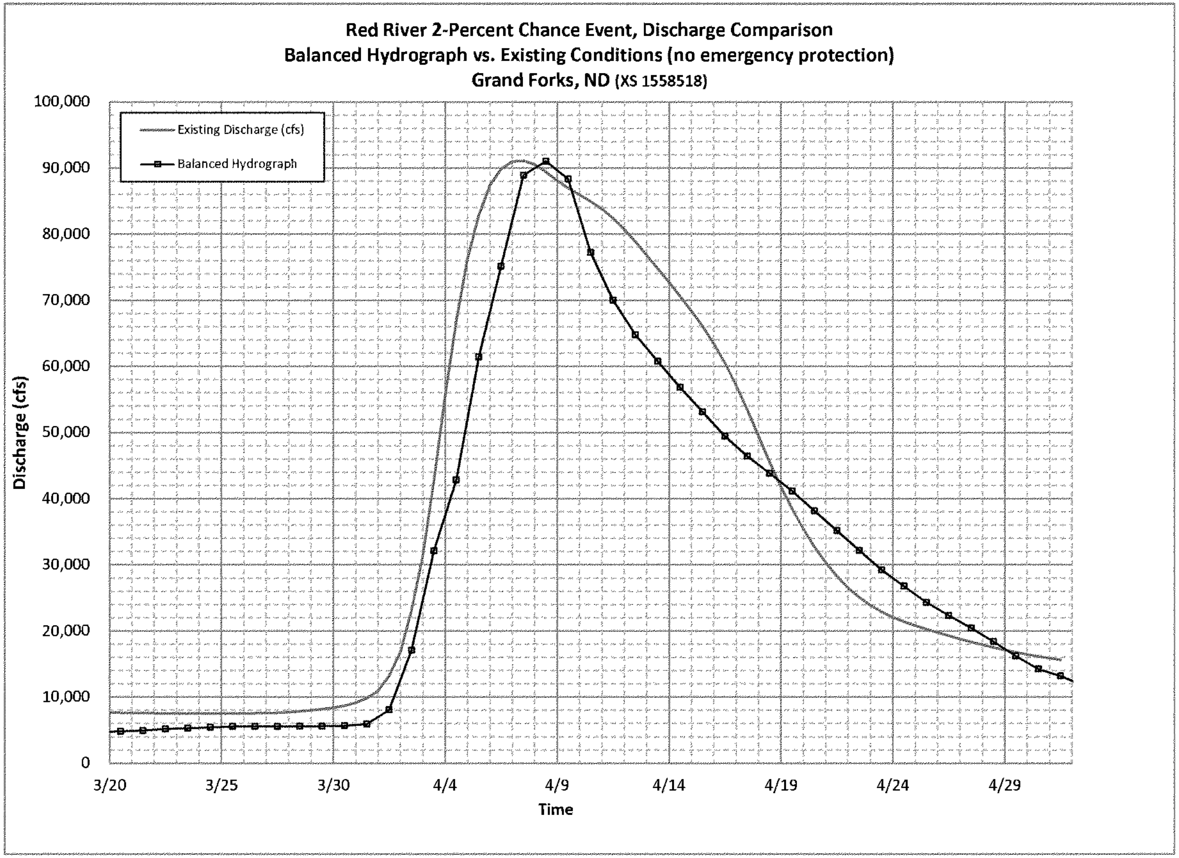


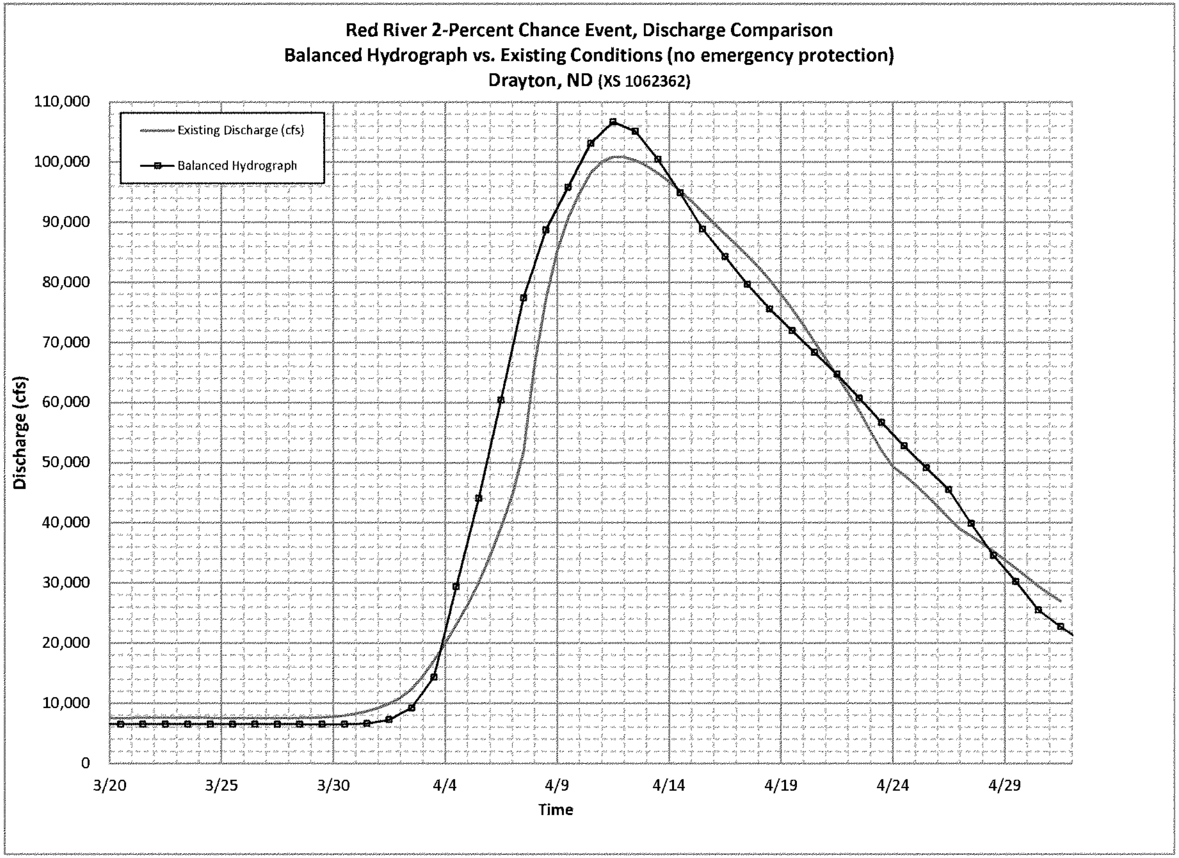

Red River 2-Percent Chance Event, Discharge Comparison
Balanced Hydrograph vs. Existing Conditions (no emergency protection)
Hickson, ND (XS 2563754)
Existing Discharge (cfs)
Balanced Hydrograph
Discharge (cfs)
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

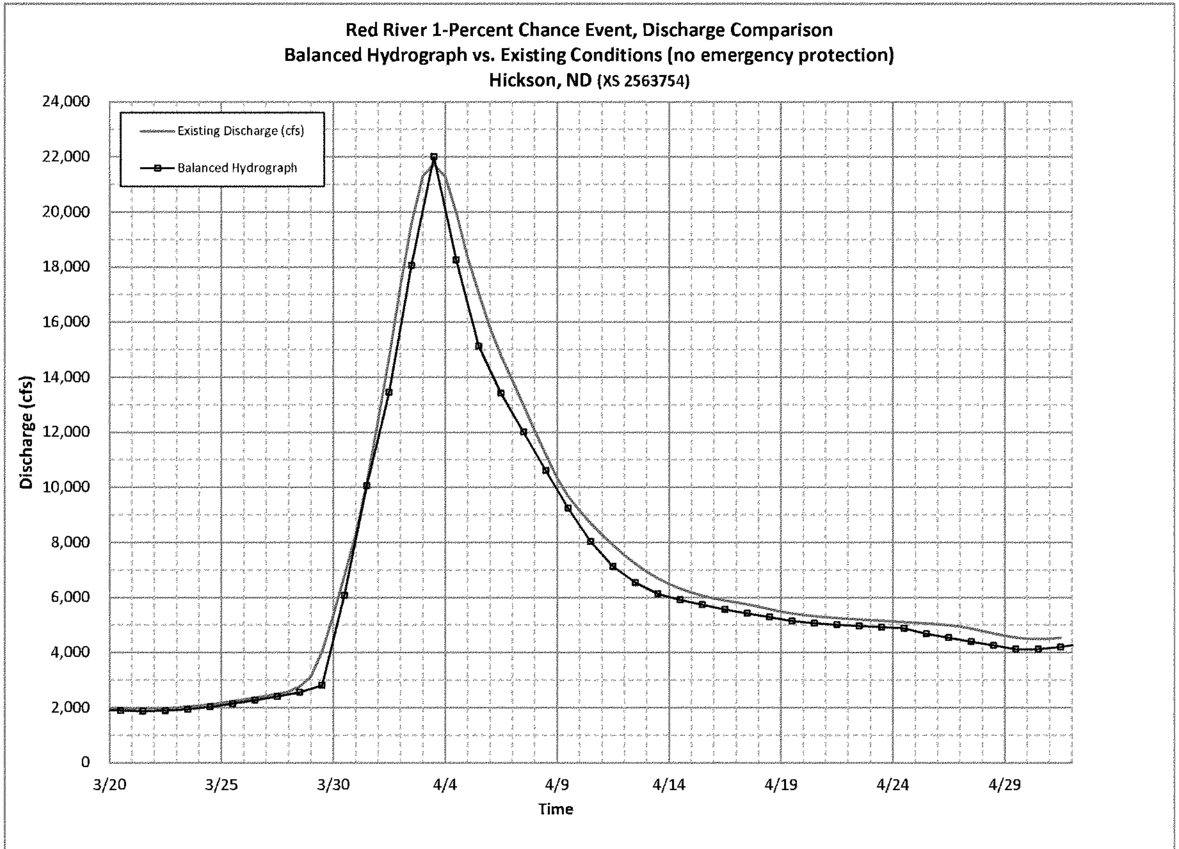

Red River 2-Percent Chance Event, Discharge Comparison
Balanced Hydrograph vs. Existing Conditions (no emergency protection)
Fargo Gage - Fargo, ND (XS 2388223)
Existing Discharge (cfs)
Balanced Hydrograph
Discharge (cfs)
30,000
25,000
20,000
15,000
10,000
5,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

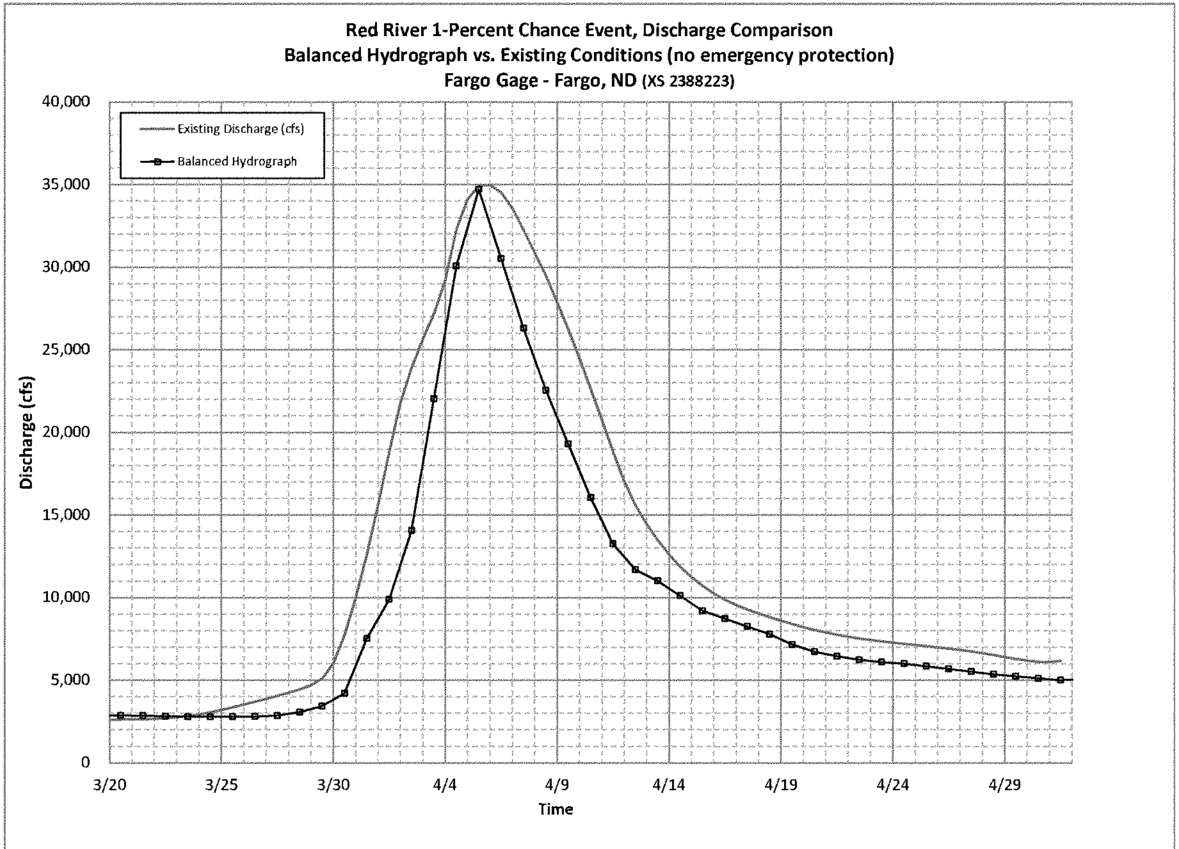

Red River 2-Percent Chance Event, Discharge Comparison
Balanced Hydrograph vs. Existing Conditions (no emergency protection)
Halstad, MN (XS 1981580)
Existing Discharge (cfs)
Balanced Hydrograph
Discharge (cfs)
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

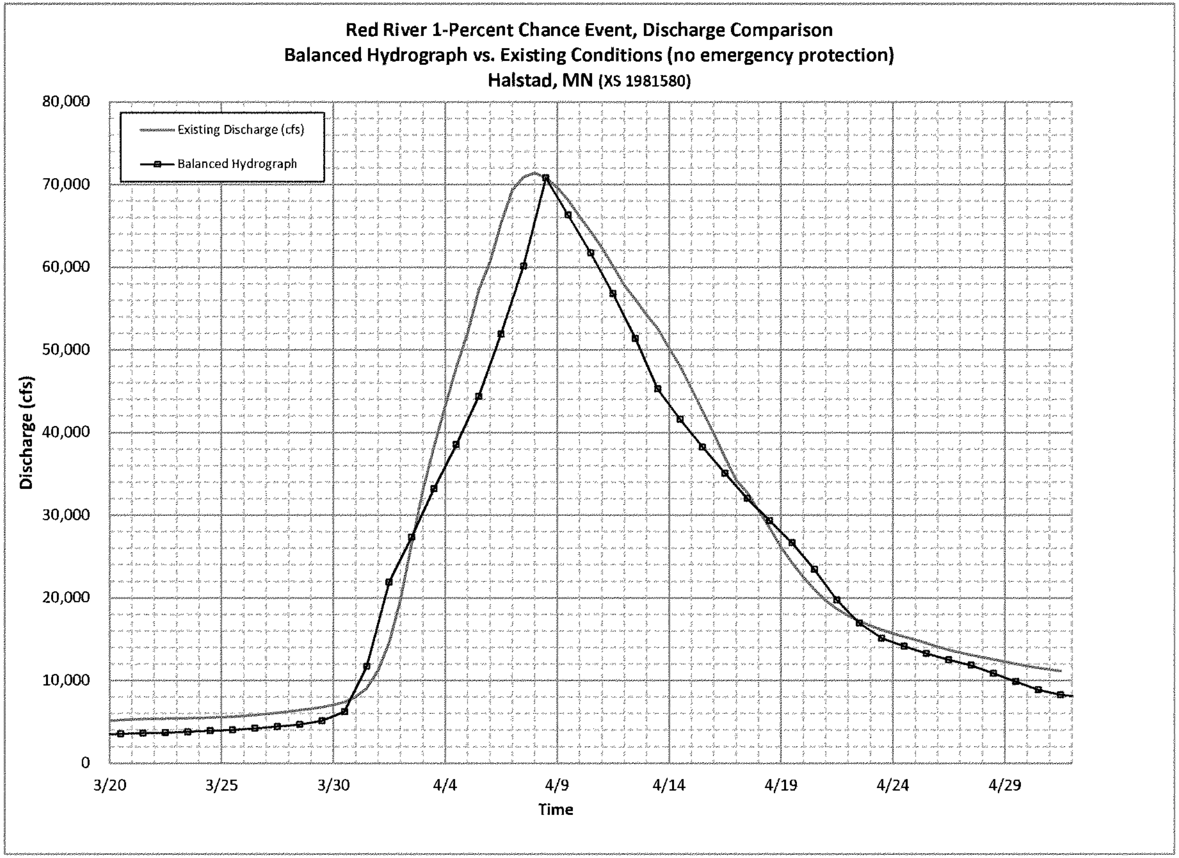

Red River 2-Percent Chance Event, Discharge Comparison
Balanced Hydrograph vs. Existing Conditions (no emergency protection)
Thompson, ND (XS 1667877)
Existing Discharge (cfs)
Balanced Hydrograph
Discharge (cfs)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

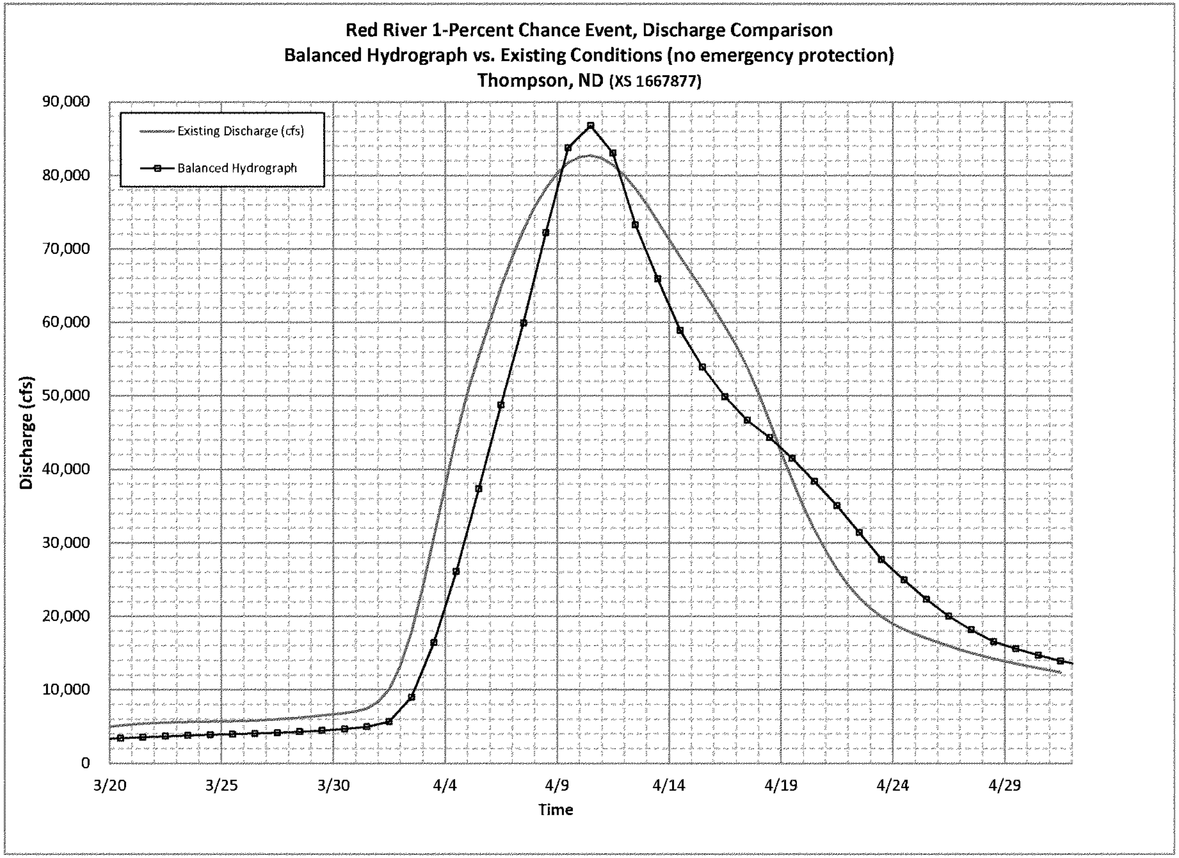

Red River 2-Percent Chance Event, Discharge Comparison
Balanced Hydrograph vs. Existing Conditions (no emergency protection)
Grand Forks, ND (XS 1558518)
Existing Discharge (cfs)
Balanced Hydrograph
Discharge (cfs)
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

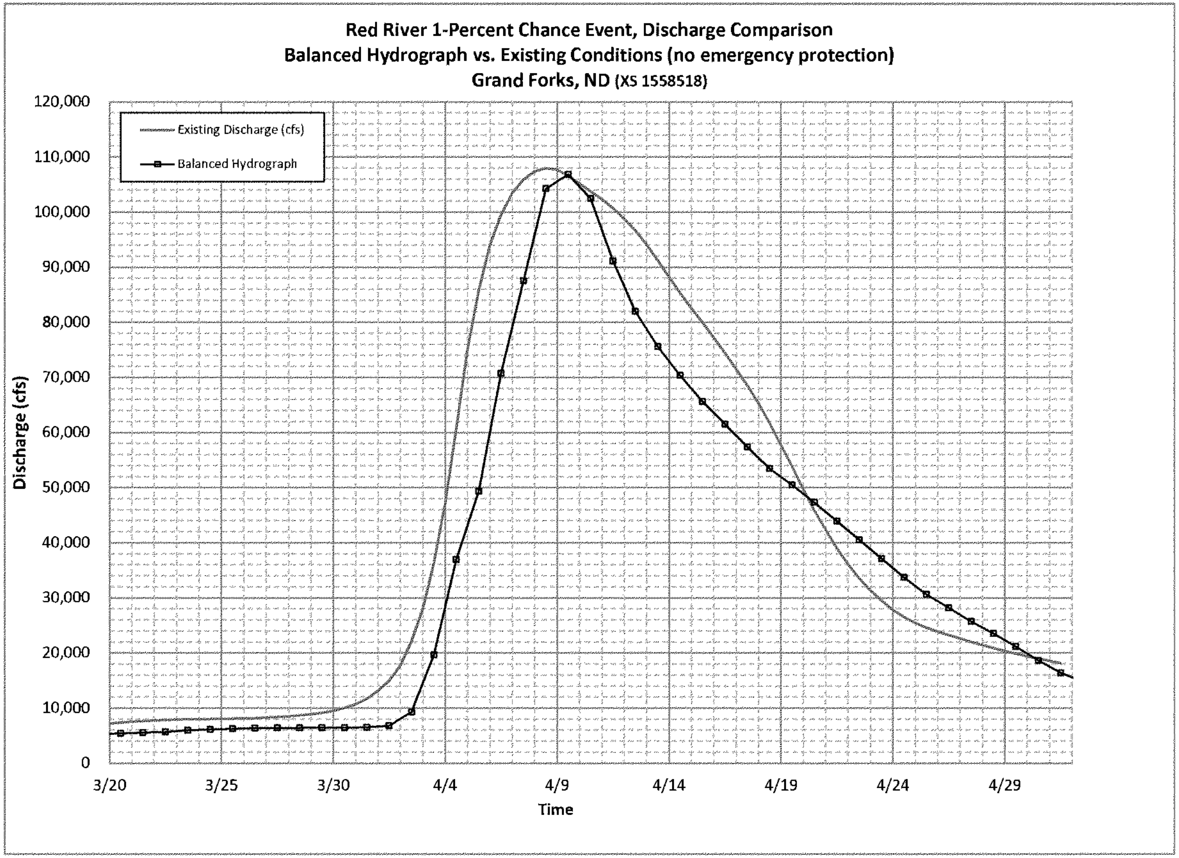

Red River 2-Percent Chance Event, Discharge Comparison
Balanced Hydrograph vs. Existing Conditions (no emergency protection)
Drayton, ND (XS 1062362)
Existing Discharge (cfs)
Balanced Hydrograph
Discharge (cfs)
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

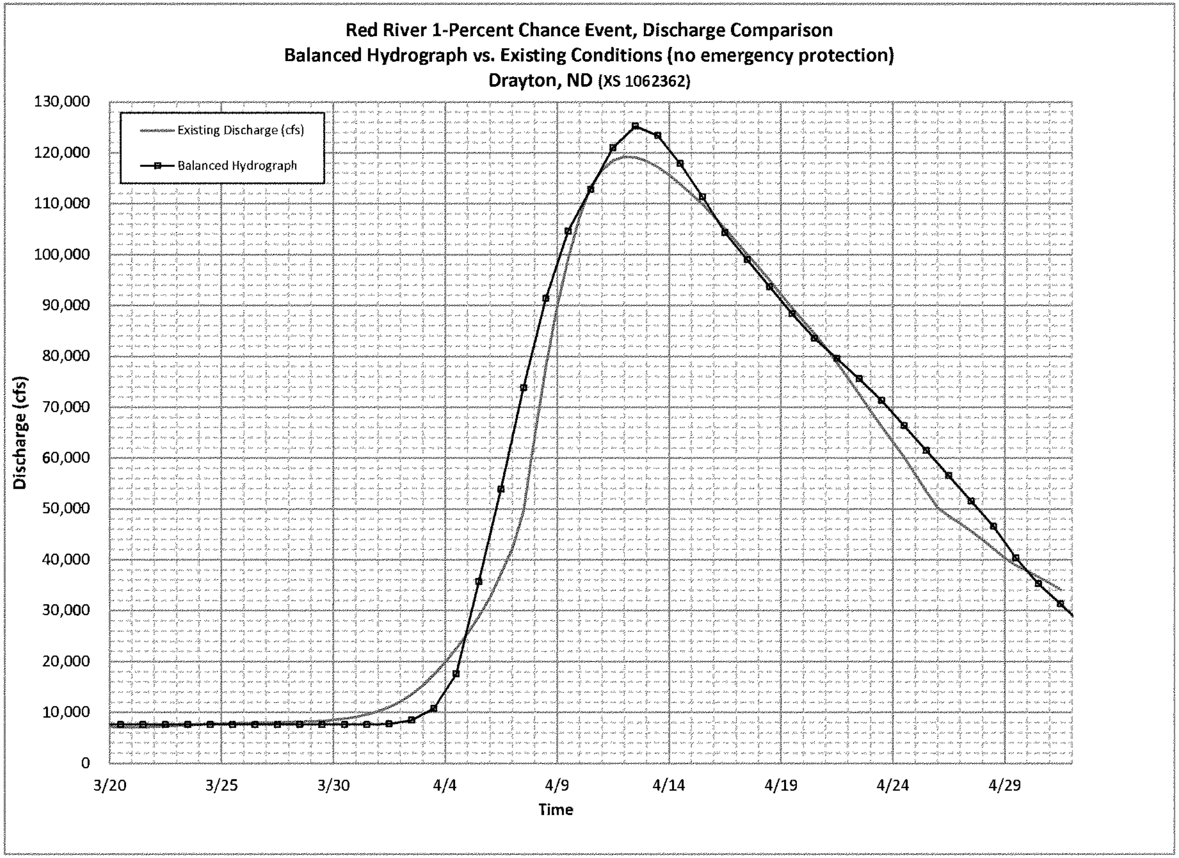

Red River 1-Percent Chance Event, Discharge Comparison
Balanced Hydrograph vs. Existing Conditions (no emergency protection)
Hickson, ND (XS 2563754)
Existing Discharge (cfs)
Balanced Hydrograph
Discharge (cfs)
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

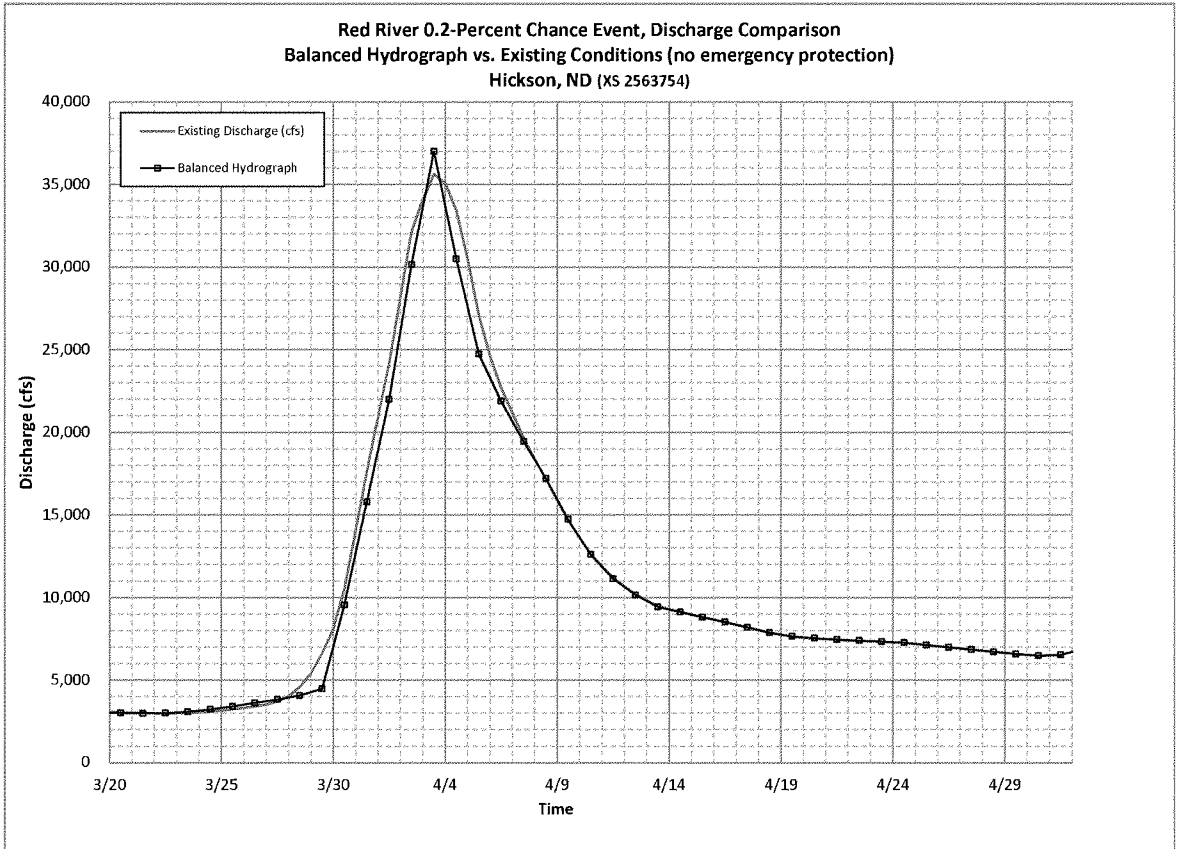

Red River 1-Percent Chance Event, Discharge Comparison
Balanced Hydrograph vs. Existing Conditions (no emergency protection)
Fargo Gage - Fargo, ND (XS 2388223)
Existing Discharge (cfs)
Balanced Hydrograph
Discharge (cfs)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

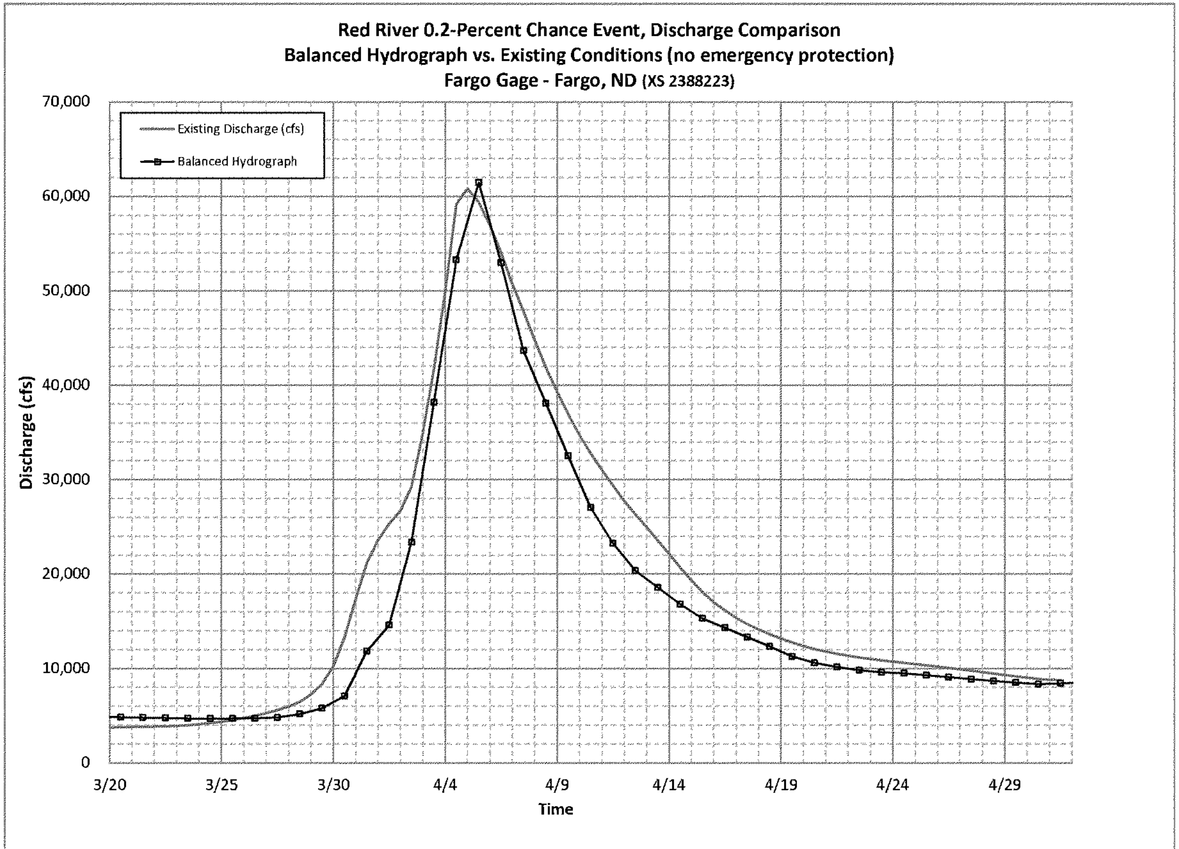

Red River 1-Percent Chance Event, Discharge Comparison
Balanced Hydrograph vs. Existing Conditions (no emergency protection)
Halstad, MN (XS 1981580)
Existing Discharge (cfs)
Balanced Hydrograph
Discharge (cfs)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

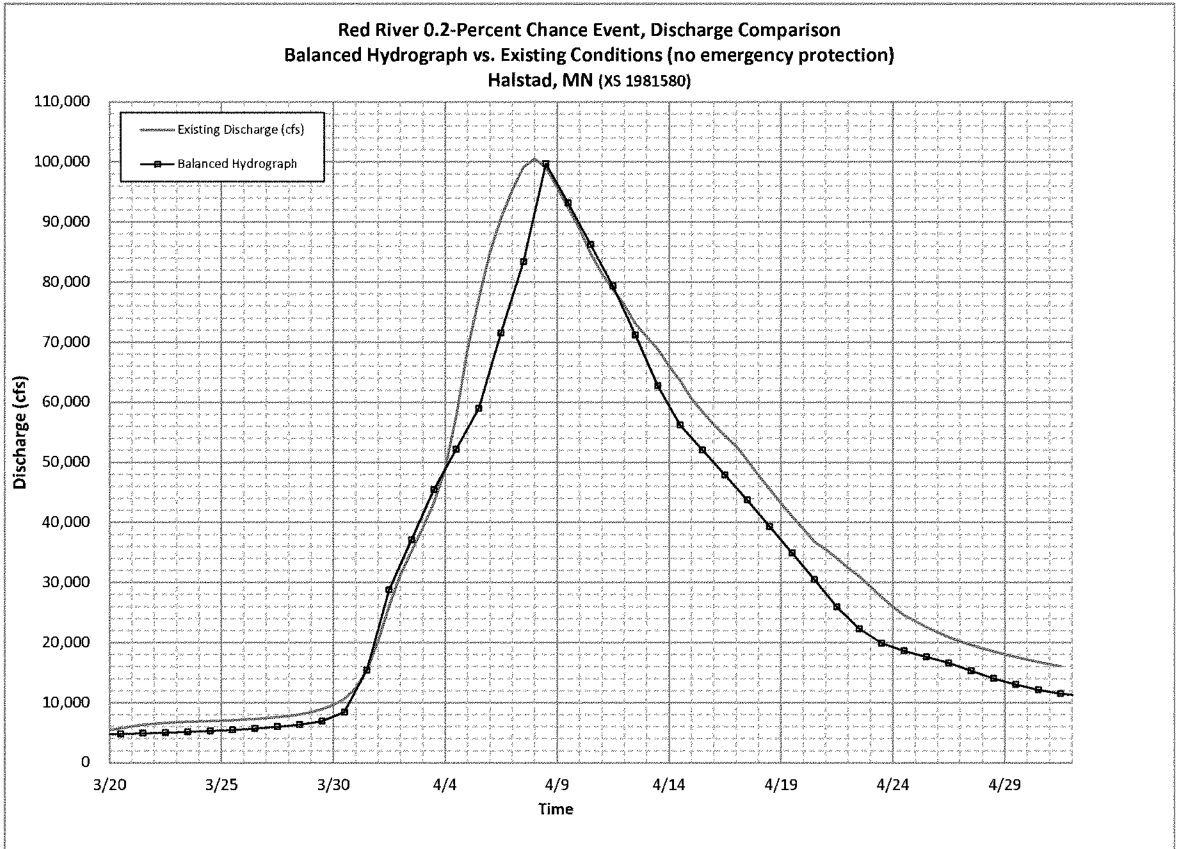

Red River 1-Percent Chance Event, Discharge Comparison
Balanced Hydrograph vs. Existing Conditions (no emergency protection)
Thompson, ND (XS 1667877)
Existing Discharge (cfs)
Balanced Hydrograph
Discharge (cfs)
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

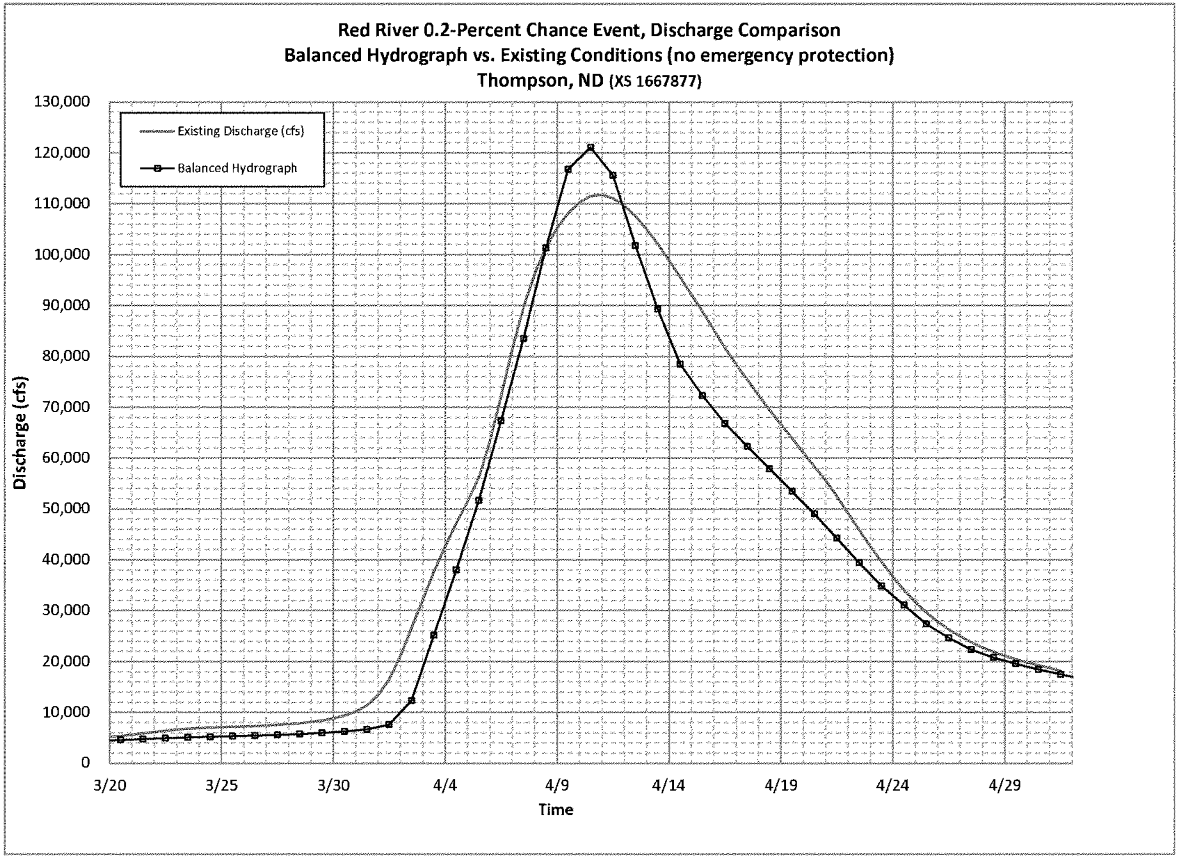

Red River 1-Percent Chance Event, Discharge Comparison
Balanced Hydrograph vs. Existing Conditions (no emergency protection)
Grand Forks, ND (XS 1558518)
Existing Discharge (cfs)
Balanced Hydrograph
Discharge (cfs)
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time


Red River 1-Percent Chance Event, Discharge Comparison
Balanced Hydrograph vs. Existing Conditions (no emergency protection)
Drayton, ND (XS 1062362)
Existing Discharge (cfs)
Balanced Hydrograph
Discharge (cfs)
130,000
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time


Red River 0.2-Percent Chance Event, Discharge Comparison
Balanced Hydrograph vs. Existing Conditions (no emergency protection)
Hickson, ND (XS 2563754)
Existing Discharge (cfs)
Balanced Hydrograph
Discharge (cfs)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time


Red River 0.2-Percent Chance Event, Discharge Comparison
Balanced Hydrograph vs. Existing Conditions (no emergency protection)
Fargo Gage - Fargo, ND (XS 2388223)
Existing Discharge (cfs)
Balanced Hydrograph
Discharge (cfs)
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time


Red River 0.2-Percent Chance Event, Discharge Comparison
Balanced Hydrograph vs. Existing Conditions (no emergency protection)
Halstad, MN (XS 1981580)
Existing Discharge (cfs)
Balanced Hydrograph
Discharge (cfs)
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time


Red River 0.2-Percent Chance Event, Discharge Comparison
Balanced Hydrograph vs. Existing Conditions (no emergency protection)
Thompson, ND (XS 1667877)
Existing Discharge (cfs)
Balanced Hydrograph
Discharge (cfs)
130,000
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
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0
3/20
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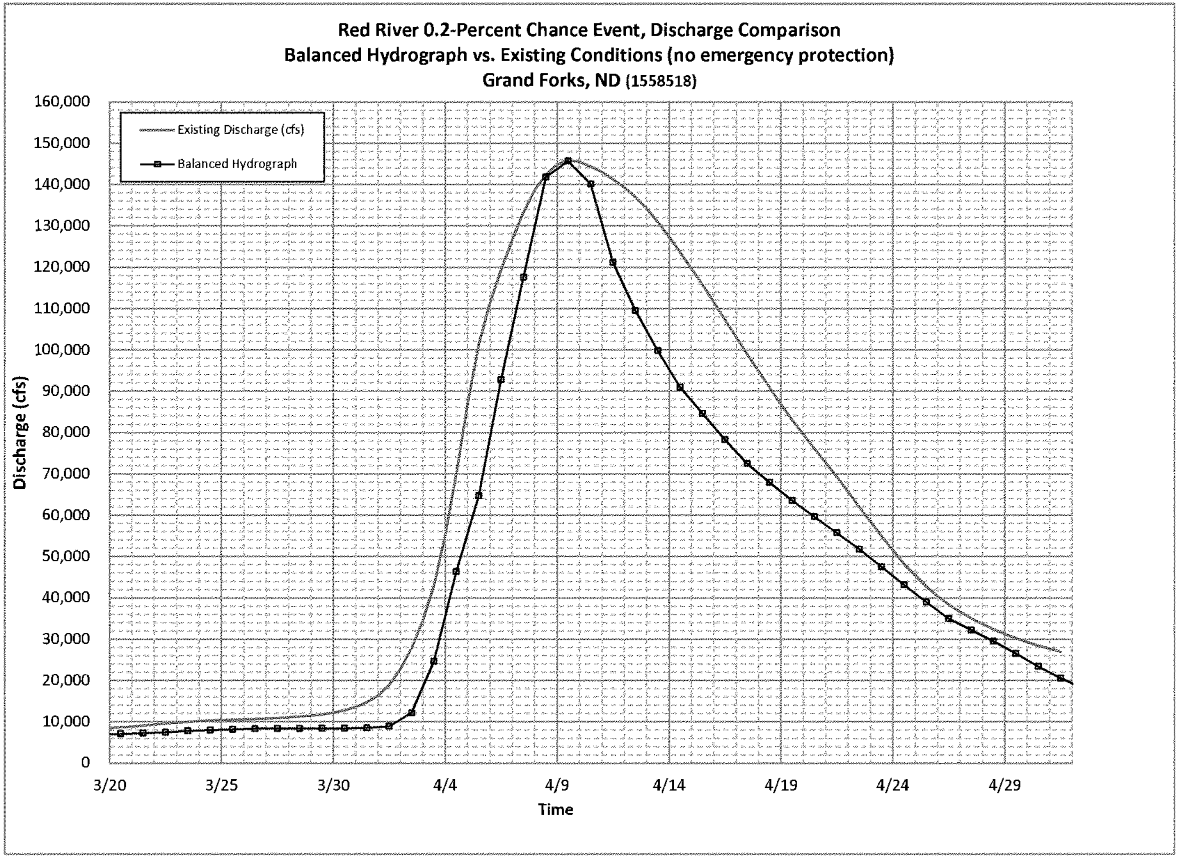
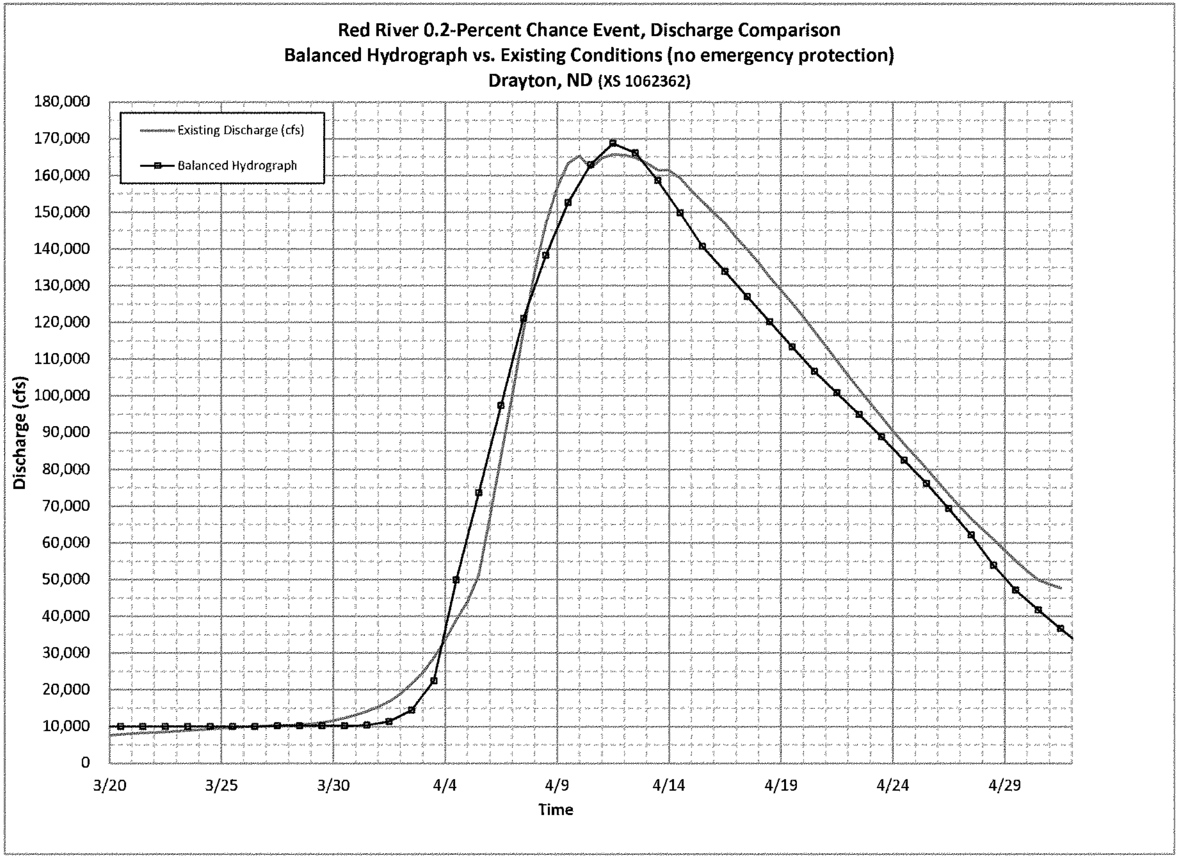
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time


Red River 0.2-Percent Chance Event, Discharge Comparison
Balanced Hydrograph vs. Existing Conditions (no emergency protection)
Grand Forks, ND (1558518)
Existing Discharge (cfs)
Balanced Hydrograph
Discharge (cfs)
160,000
150,000
140,000
130,000
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time


Red River 0.2-Percent Chance Event, Discharge Comparison
Balanced Hydrograph vs. Existing Conditions (no emergency protection)
Drayton, ND (XS 1062362)
Existing Discharge (cfs)
Balanced Hydrograph
Discharge (cfs)
180,000
170,000
160,000
150,000
140,000
130,000
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

Appendix B – Hydraulics
Existing Condition

Exhibit F

Sensitivity Analysis – (Houston Engineering, Inc.)

MEMO

Technical Memorandum

HoustonEngineering Inc.

To: File: FM Metro Feasibility Study **From:** Greg Thompson

Date: October 5, 2010 **Subject:** Sensitivity Analysis

As part of the ATR comment response, a sensitivity analysis was completed. Specific requests were made as well as other issues identified by engineers familiar with the model to better identify the sensitivity that the assumptions have on the results. All of the sensitivity analyses were conducted with the existing conditions model and the "with project" ND Diversion model for the 1-percent chance event. The following is a list of topics visited in the sensitivity analysis as well as a summary and the results of each:

1. **Storage Area Weir Coefficients**
2. **Lateral Structure Weir Coefficients**
3. **Storage Area and Lateral Structure Weir Coefficients - Combined**
4. **Diversion Channel "n" value**
5. **Hydrology**

1. Storage Area Weir Coefficients

Analysis

Emergency protection through the Fargo Moorhead communities is not accounted for in any of the analyzed alternatives or in the existing conditions base model. This allows significant flood events to convey flood water through the normally protected parts of the Cities as well as other areas modeled as storage areas. Modelers and reviewers have expressed concern with the magnitude of the storage area conveyance and with the sensitivity this may have on the results of the modeling (downstream impacts). The amount of water conveyed through the storage areas is in direct correlation with the weir coefficients in the storage area connections. This analysis compared weir coefficients of 2.0, 2.6 (default) and 3.0.

Results

As expected, the weir coefficients affect the timing of the downstream hydrographs. As the weir coefficients are reduced, less water is conveyed through the storage areas and more is required to pass through the channel, lagging the hydrograph and increasing stage on the Red River. Reducing the weir coefficients by 25% (Default 2.6 to 2.0), causes an average downstream impact increase of 0.05 feet. Increasing the weir coefficients by 15% (Default 2.6 to 3.0) causes an average downstream impact reduction of 0.02 feet. Therefore, changing the storage area connection weir coefficients has little effect on the downstream impacts. See **Table 1.0** for downstream impact comparisons. **Figure 1.0** shows the general trend of downstream impacts. The magnitude of the impacts is directly related to the floodplain width. The slight increases and decreases in impacts related to the sensitivity analysis are also relative to the magnitude of the original downstream impacts.

2. Lateral Structure Weir Coefficients

Analysis
Lateral structures convey water from the primary channel to the overbank storage areas. The original lateral structure weir coefficient was set at 2.0. It was set lower than the storage area connections to reflect a lower efficiency discharging perpendicular to the conveyance of the channel. The sensitivity comparison consisted of a change from 2.0 to 2.6 and 2.0 to 1.5.

Results
Changing the lateral structure weir coefficients did not have a significant impact on the model. The general trend of increasing or decreasing the weir coefficients was as expected. A lower weir coefficient reduces the conveyance to the storage areas and increases the conveyance through the main channel. The results show an increase of 260 cfs (1%) in the channel during a 1-percent chance event and a similar reduction through the storage areas. Raising the weir coefficients had similar effects, however reversed.

3. Storage Area and Lateral Structure Weir Coefficients - Combined

Analysis
It was anticipated that changing the storage area connection and lateral structure weir coefficients would behave differently than analyzing them individually. The lateral structures may restrict water from leaving the main channel, however if the storage area connections are not changed, the storage areas will not pass as much water as they would if the storage area connections and lateral structures were changed together. To analyze this sensitivity, the lateral structure weir coefficients were set to 1.5 and the storage area connection weir coefficients were set to 2.0 (both lowered). This would be the most restrictive overbank scenario of the sensitivity analysis. Another scenario was completed that would reflect a higher overbank storage area conveyance. Here, the storage area connection weir coefficients were set at 3.0, and the lateral structure weir coefficients were set at 3.0.

Results
High weir coefficients conveyed more water outside of the channel resulting in a lower water surface profile. Lower weir coefficients retained more of the water in the channel at a higher water surface profile. Either extreme provided an approximate 500 cfs shift in water between the channel and the storage areas. The discharge differences carried throughout the model beyond Halstad, MN. The resulting sensitivity was greater than analyzing the coefficients individually. However, the impacts were still relatively low with extreme impacts of +0.16' to -0.12' near Climax where the 1-percent chance event impact was originally over 2 feet. See **Table 3.0** for combined downstream impact comparisons with the varied weir coefficients.

MEMO

HoustonEngineering Inc.

4. Diversion Channel "n" value

Analysis
The default channel roughness for the diversion channels were 0.03. The North Dakota Diversion was used in this sensitivity analysis. The channel "n" was increased to 0.035 and 0.04. Following the 2009 flood, the Winnipeg Diversion was analyzed and the resulting documentation supported a manning's roughness "n" value of 0.03.

Results
Increasing the "n" value to 0.035 resulted in a downstream reduction of less than 0.1 foot and an upstream stage increase of up to 0.15 feet. As anticipated, water shifted from the diversion channel to the Red River causing stage impacts at the diversion inlet.

Increasing the "n" value to 0.04 resulted in a downstream reduction of approximately 0.1 foot and an upstream stage increase of up to 0.4 feet. As with the 0.035 analysis, water shifted from the diversion channel to the Red River causing stage impacts at the diversion inlet.

5. Hydrology

Analysis
Select sites along the Red River have USGS gages with stage and discharge information. Locations along the Red River between USGS gaging sites have been estimated. The hydrology sensitivity analysis was conducted to see how a range of assumptions would impact the model and results. Fargo and Halstad have known USGS gages. An intermediate evaluation point is near Georgetown, MN downstream of the Sheyenne and Buffalo Rivers' confluences with the Red River.

a) A north-south shift was conducted to determine the sensitivity of hydrograph magnitude near Georgetown. This analysis consisted of a reduction in peak discharge near Georgetown of 25%. Additional water was introduced into the system between Georgetown and Halstad to make up the remaining portion of the hydrograph at Halstad.

b) A reversed north-south shift was also conducted. This increases the peak Red River discharge near Georgetown by 25%, and a reduction in contributions between Georgetown and Halstad.

c) Engineers familiar with the hydrology contributed from the North Dakota side of the project expressed concern with the significantly high flows along the Sheyenne and Maple Rivers. Assuming that the original Red River hydrograph near Georgetown is accurate, an east-west shift was conducted to identify the sensitivity of the distribution of inflows between Fargo and Georgetown. The comparison reduced the given Maple River flows and Sheyenne River breakout flows by 25%. To maintain volume near Georgetown, this resulted in a 60%

increase to the Buffalo River hydrograph. The original balanced hydrograph for the Buffalo River near Dilworth was near the low end of the accepted values. Increasing the Buffalo River by 60% raised it near the known 1-percent chance event discharge on the Buffalo River.

d) To magnify the east-west shift and also incorporate a north-south shift, the Maple River and Sheyenne River breakout flows were reduced by 40%. The Buffalo River remained at the 60% increase. This resulted in a smaller hydrograph at Georgetown and an increase in water added between Georgetown and Halstad.

Results

All of the hydrology sensitivities had equal hydrology and hydraulic conditions upstream of Fargo/Moorhead and the diversion alternatives had similar diverted discharges. Therefore, the only changes in the comparison are to hydrographs between Fargo and Halstad.

a) North South Shift - Reducing the hydrograph at Georgetown also included increasing contributions between Georgetown and Halstad. Downstream discharges contributing to the system have their own timing in the existing condition hydrograph. The diversion project reduced the time the flood wave requires to travel to a downstream location, therefore stacking the diverted flow on top of the locally contributing hydrographs. This is shown by the increase in impacts at downstream locations with the north-south shift (See **Table 5a**).

b) North South Shift (reversed) – Less water is introduced between Georgetown and Halstad resulting in reduced downstream impacts. See **Table 5b**.

c) East-West Shift (25%) – The impact of this shift was very minimal (< 0.05'). This is attributed to the volume of water upstream of the Fargo/Moorhead area remaining the same, the amount of diverted water remaining the same, and the hydrographs downstream of the project remaining the same. This also shows that the impacts of the project are not sensitive to the Maple River and Sheyenne River hydrographs, but directly related to the amount of water being diverted from upstream along the Red River and Wild Rice River. It appears as though the timing of the hydrographs between the Maple/Sheyenne and the Red River is similar between existing conditions and with diversion conditions and their flowpaths are relatively the same length. See **Table 5c**.

d) East-West Shift (40%) - The impact of this shift was also very minimal. There were minor reductions in the impacts directly downstream of the diversion outlet followed by minor increases (+0.02') near the highest impact location (Climax). See **Table 5d**.

Table 1.0 - Varying Storage Area Connection Weir Coefficients

North Dakota East 35K Diversion Downstream Impacts 1-Percent Chance Event				
Location	**Station**	ND Diversion with Weir = 2.0	ND Diversion with Weir = 2.6 (default)	ND Diversion with Weir = 3.0
		Benefit/Impact (ft)	Benefit/Impact (ft)	Benefit/Impact (ft)
Drayton Gage	1062682	0.45	0.44	0.44
ND SH#17/ MN SH317	1223183	0.40	0.39	0.39
Co. Hwy 15	1315673	0.34	0.33	0.32
Oslo Gage	1416287	0.40	0.39	0.38
DS Turtle River	1419932	0.36	0.35	0.35
US Turtle River	1440916	0.33	0.32	0.32
DS Grand Forks Levees	1533523	0.45	0.43	0.42
DS Red Lake River	1560870	1.01	0.98	0.96
32nd Ave, Grand Forks	1580152	1.22	1.17	1.15
Thompson Gage	1667665	1.19	1.13	1.09
Co. Hwy 25/ Co. Rd 221	1719816	1.95	1.86	1.81
DS Sandhill River/ Climax	1763746	2.12	2.02	1.97
Maximum Impact Location	1782305	2.14	2.02	1.98
Nielsville	1829650	1.92	1.82	1.78
DS Marsh River	1864960	1.66	1.57	1.55
US Goose River/ Shelly	1890722	1.26	1.20	1.17
Co. Rd 139	1951761	0.84	0.80	0.78
Halstad Gage	1981580	0.90	0.86	0.84
Hendrum	2038359	0.95	0.90	0.88
Perley	2129181	0.61	0.58	0.58
Georgetown	2193941	0.67	0.65	0.63
North River/ Clay Co. Hwy 93	2305647	-5.59	-5.56	-5.52
19th Ave N Fargo/ 28th Ave N Moorhead	2360321	-7.51	-7.44	-7.37
Fargo Gage (13th Ave S, 12th Ave S)	2388223	-9.61	-9.47	-9.37
US Rose Coulee/ US 50th Ave S Moorhead	2430241	-9.61	-9.52	-9.48
52nd Ave S Fargo/ 60th Ave S Moorhead	2438085	-9.79	-9.73	-9.69
US ND Wild Rice River	2484618	-8.77	-8.77	-8.76
US Diversion	2531338	0.02	0.02	0.02
Hickson Gage	2563878	0.00	0.01	0.01

Figure 1.0 - Typical Downstream Impact Variation (Related to floodplain width)

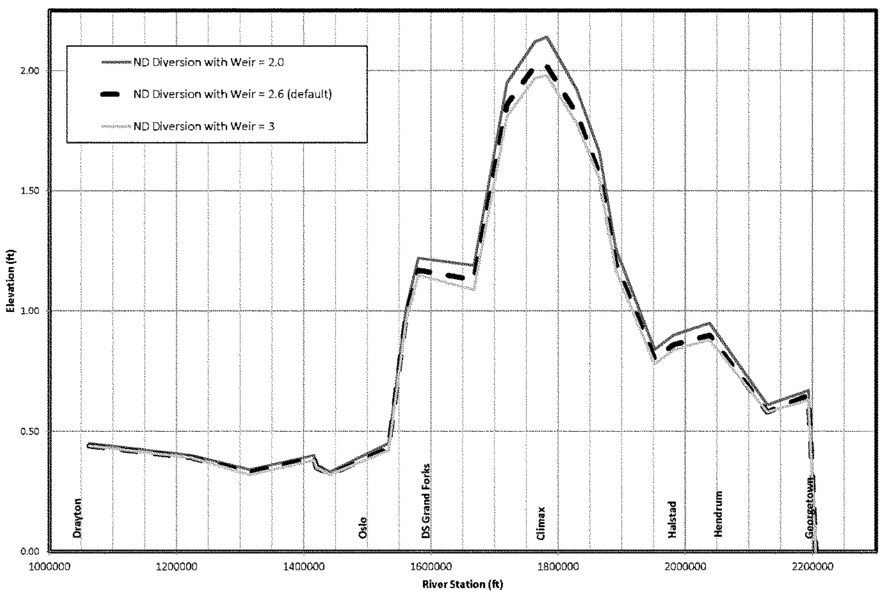


Table 3.0 - Varying Storage Area Connection and Lateral Structure Weir Coefficients

North Dakota East 35K Diversion Downstream Impacts 1-Percent Chance Event						
Location	Station	ND Diversion with SAC weir = 2.0 LS weir = 1.5		ND Diversion Original	ND Diversion with SAC weir = 3.0 LS weir = 3.0	
		Benefit/Impact (ft)		Benefit/Impact (ft)	Benefit/Impact (ft)	
Drayton Gage	1062682	0.47	7%	0.44	0.43	-2%
ND SH#17/ MN SH317	1223183	0.40	3%	0.39	0.38	-3%
Co. Hwy 15	1315673	0.35	6%	0.33	0.31	-6%
Oslo Gage	1416287	0.42	8%	0.39	0.37	-5%
DS Turtle River	1419932	0.38	9%	0.35	0.34	-3%
US Turtle River	1440916	0.35	9%	0.32	0.31	-3%
DS Grand Forks Levees	1533523	0.47	9%	0.43	0.41	-5%
DS Red Lake River	1560870	1.08	10%	0.98	0.94	-4%
32nd Ave, Grand Forks	1580152	1.22	4%	1.17	1.11	-5%
Thompson Gage	1667665	1.16	3%	1.13	1.05	-7%
Co. Hwy 25/ Co. Rd 221	1719816	1.97	6%	1.86	1.73	-7%
DS Sandhill River/ Climax	1763746	2.16	7%	2.02	1.88	-7%
Maximum Impact Location	1782305	2.18	8%	2.02	1.90	-6%
Nielsville	1829650	1.96	8%	1.82	1.70	-7%
DS Marsh River	1864960	1.70	8%	1.57	1.48	-6%
US Goose River/ Shelly	1890722	1.29	8%	1.20	1.11	-8%
Co. Rd 139	1951761	0.87	9%	0.80	0.74	-8%
Halstad Gage	1981580	0.93	8%	0.86	0.80	-7%
Hendrum	2038359	0.99	10%	0.90	0.82	-9%
Perley	2129181	0.64	10%	0.58	0.54	-7%
Georgetown	2193941	0.70	8%	0.65	0.59	-9%
North River/ Clay Co. Hwy 93	2305647	-5.52	-1%	-5.56	-5.56	0%
19th Ave N Fargo/ 28th Ave N Moorhead	2360321	-7.51	1%	-7.44	-7.37	-1%
Fargo Gage (13th Ave S, 12th Ave S)	2388223	-9.51	0%	-9.47	-9.51	0%
US Rose Coulee/ US 50th Ave S Moorhead	2430241	-9.67	2%	-9.52	-9.37	-2%
52nd Ave S Fargo/ 60th Ave S Moorhead	2438085	-9.88	2%	-9.73	-9.57	-2%
US ND Wild Rice River	2484618	-8.90	1%	-8.77	-8.58	-2%
US Diversion	2531338	-0.02	0%	0.02	0.07	0%
Hickson Gage	2563878	-0.02	0%	0.01	0.05	0%

SAC = Storage Area Connection
LS = Lateral Structure

Table 5a Sensitivity Analysis - Hydrology Reduced 25% between Fargo and Buffalo								
North Dakota East 35K Diversion - 1-Percent Chance Event								
Location	Station	Existing No Protection Elevation		ND East 35K Diversion Elevation		Difference Project vs. Existing No Protection		Original Submittal
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	
Thompson Gage	1,667,665	847.74	86413	849.00	98251	1.26	11838	1.14
Co. Hwy 25/ Co. Rd 221	1,719,816	853.93	86102	856.01	98092	2.08	11990	1.88
DS Sandhill River/ Climax	1,763,746	857.88	85859	860.15	97900	2.27	12041	2.06
Maximum Impact Location	1,782,305	859.24	81675	861.54	93534	2.30	11859	2.06
Nielsville	1,829,650	861.81	80622	863.87	92482	2.06	11859	1.87
DS Marsh River	1,864,960	863.14	80074	864.93	92115	1.79	12040	1.63
US Goose River/ Shelly	1,890,722	865.21	64673	866.59	72132	1.38	7459	1.24
Co. Rd 139	1,951,761	867.39	70116	868.33	82698	0.94	12582	0.82
Halstad Gage	1,981,580	868.67	69836	869.73	84114	1.06	14278	0.88
Hendrum	2,038,359	873.28	60661	874.34	69838	1.06	9177	0.92
Perley	2,129,181	877.80	50883	878.43	57341	0.63	6458	0.59
Georgetown	2,193,941	881.79		882.38		0.59	9687	0.67
North River/ Clay Co. Hwy 93	2,305,647	893.53		887.62		-5.91		-5.58
19th Ave N Fargo/ 28th Ave N Moorhead	2,360,321	898.98		891.34		-7.64		-7.43
Fargo Gage (13th Ave S, 12th Ave S)	2,388,223	903.00 (*40.26)		893.48 (*30.74)		-9.60	-13542	-9.46
US Rose Coulee/ US 50th Ave S Moorhead	2,430,241	906.15		896.55		-9.60		-9.52
52nd Ave S Fargo/ 60th Ave S Moorhead	2,438,085	907.01		897.21		-9.80		-9.72
US ND Wild Rice River	2,484,618	910.43		901.65		-8.78	-14165	-8.77
US Diversion	2,531,338	914.89		914.90		0.01		0.02
Hickson Gage	2,563,878	917.11	24601	917.11	24542	0.00	-59	0.01

* Flood stage at USGS Gaging Station 05054000, Fargo, ND

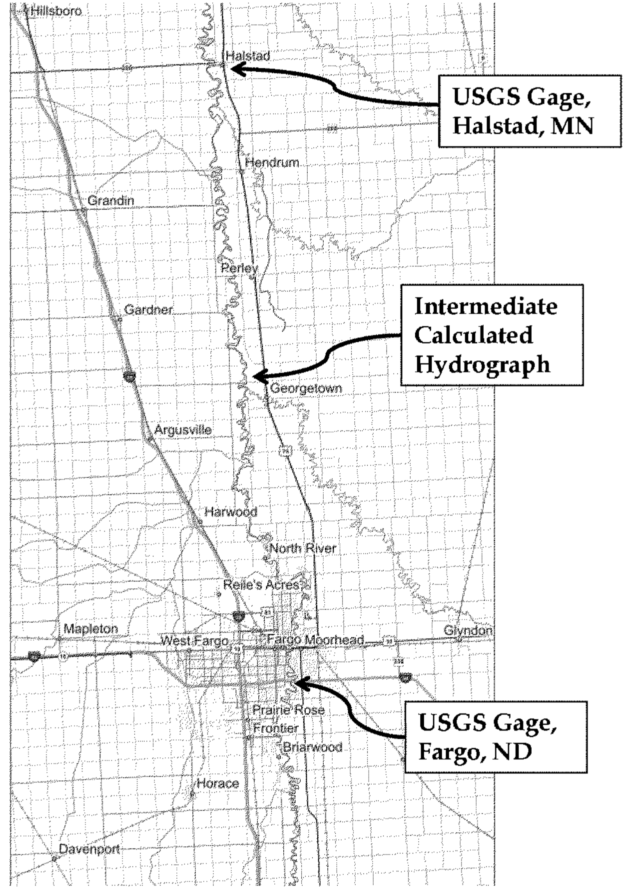
Table 5b Sensitivity Analysis - Hydrology Increased 25% between Fargo and Buffalo								
North Dakota East 35K Diversion - 1-Percent Chance Event								
Location	Station	Existing No Protection Elevation		ND East 35K Diversion Elevation		Difference Project vs. Existing No Protection		Original Submittal
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	
Thompson Gage	1,667,665	847.75	86584	848.84	96538	1.09	9954	1.14
Co. Hwy 25/ Co. Rd 221	1,719,816	853.96	86282	855.74	96303	1.78	10021	1.88
DS Sandhill River/ Climax	1,763,746	857.91	86038	859.84	96093	1.93	10055	2.06
Maximum Impact Location	1,782,305	859.28	81857	861.21	91681	1.93	9823	2.06
Nielsville	1,829,650	861.84	80811	863.58	90639	1.74	9828	1.87
DS Marsh River	1,864,960	863.16	80272	864.66	90183	1.50	9912	1.63
US Goose River/ Shelly	1,890,722	865.23	64673	866.37	72132	1.14	7459	1.24
Co. Rd 139	1,951,761	867.41	70440	868.16	79486	0.75	9046	0.82
Halstad Gage	1,981,580	868.70	70255	869.49	79788	0.79	9533	0.88
Hendrum	2,038,359	873.64	66054	874.48	74294	0.84	8240	0.92
Perley	2,129,181	878.51	61635	879.10	71002	0.59	9367	0.59
Georgetown	2,193,941	882.65		883.24		0.59	6004	0.67
North River/ Clay Co. Hwy 93	2,305,647	893.56		888.22		-5.34		-5.58
19th Ave N Fargo/ 28th Ave N Moorhead	2,360,321	898.99		891.70		-7.29		-7.43
Fargo Gage (13th Ave S, 12th Ave S)	2,388,223	903.00 (*40.26)		893.48 (*30.74)		-9.36	-13522	-9.46
US Rose Coulee/ US 50th Ave S Moorhead	2,430,241	906.15		896.68		-9.47		-9.52
52nd Ave S Fargo/ 60th Ave S Moorhead	2,438,085	907.01		897.33		-9.68		-9.72
US ND Wild Rice River	2,484,618	910.44		901.69		-8.75	-14181	-8.77
US Diversion	2,531,338	914.89		914.91		0.02		0.02
Hickson Gage	2,563,878	917.11	24586	917.12	24527	0.01	-59	0.01

Table 5c Sensitivity Analysis - West Hydrology Reduced 25%								
North Dakota East 35K Diversion - 1-Percent Chance Event								
Location	Station	Existing No Protection Elevation		ND East 35K Diversion Elevation		Difference Project vs. Existing No Protection		Original Submittal
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	
Thompson Gage	1,667,665	847.66	85868	848.82	96345	1.16	10477	1.14
Co. Hwy 25/ Co. Rd 221	1,719,816	853.83	85560	855.70	96108	1.87	10548	1.88
DS Sandhill River/ Climax	1,763,746	857.77	85312	859.80	95897	2.03	10584	2.06
Maximum Impact Location	1,782,305	859.13	81188	861.16	91540	2.03	10352	2.06
Nielsville	1,829,650	861.71	80147	863.54	90491	1.83	10344	1.87
DS Marsh River	1,864,960	863.06	79563	864.63	90048	1.57	10485	1.63
US Goose River/ Shelly	1,890,722	865.15	64673	866.35	72132	1.20	7459	1.24
Co. Rd 139	1,951,761	867.36	69856	868.15	79594	0.79	9738	0.82
Halstad Gage	1,981,580	868.64	69487	869.49	79769	0.85	10283	0.88
Hendrum	2,038,359	873.47	63762	874.36	72164	0.89	8403	0.92
Perley	2,129,181	878.19	56592	878.74	63250	0.55	6659	0.59
Georgetown	2,193,941	882.18		882.78		0.60	7627	0.67
North River/ Clay Co. Hwy 93	2,305,647	893.53		888.09		-5.44		-5.58
19th Ave N Fargo/ 28th Ave N Moorhead	2,360,321	898.98		891.58		-7.40		-7.43
Fargo Gage (13th Ave S, 12th Ave S)	2,388,223	903.00 (*40.26)		893.55 (*30.81)		-9.45	-13545	-9.46
US Rose Coulee/ US 50th Ave S Moorhead	2,430,241	906.15		896.63		-9.52		-9.52
52nd Ave S Fargo/ 60th Ave S Moorhead	2,438,085	907.01		897.28		-9.73		-9.72
US ND Wild Rice River	2,484,618	910.44		901.67		-8.77	-14178	-8.77
US Diversion	2,531,338	914.89		914.90		0.01		0.02
Hickson Gage	2,563,878	917.11	24601	917.11	24542	0.00	-59	0.01

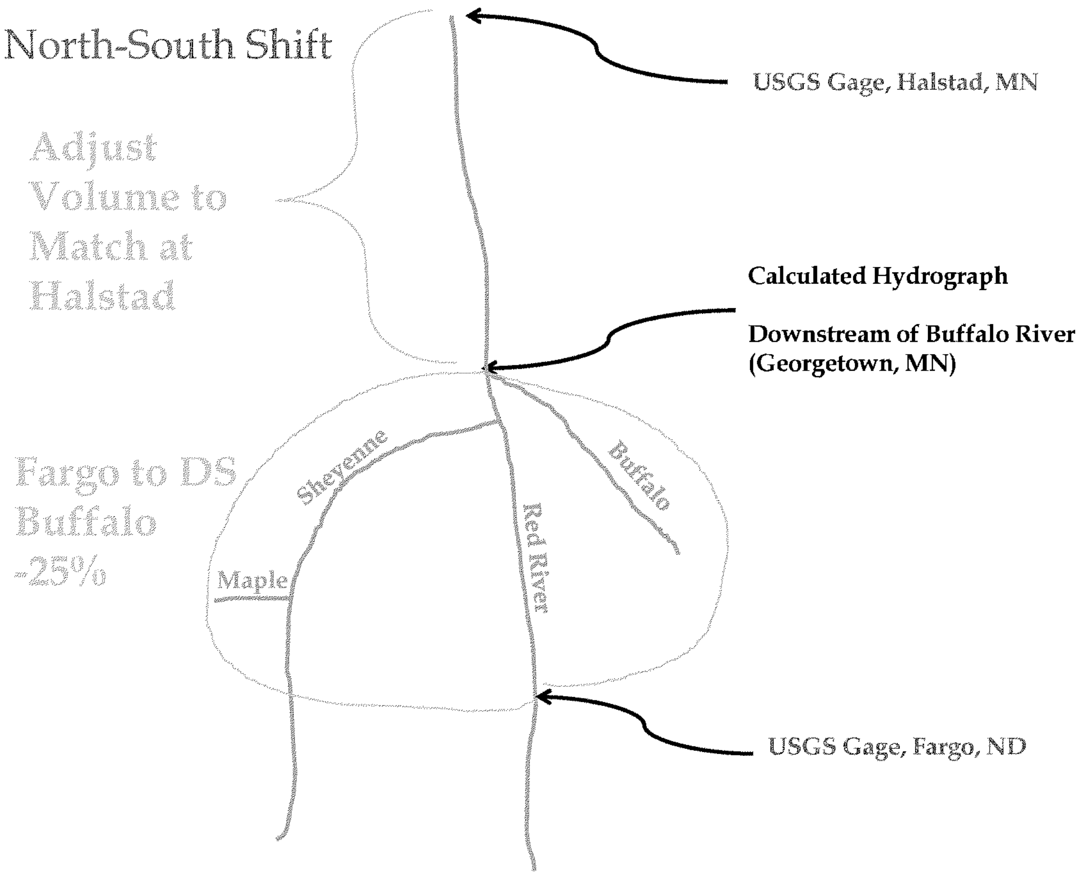
* Flood stage at USGS Gaging Station 05054000, Fargo, ND

Table 5d Sensitivity Analysis - West Hydrology Reduced 40%								
North Dakota East 35K Diversion - 1-Percent Chance Event								
Location	Station	Existing No Protection Elevation		ND East 35K Diversion Elevation		Difference Project vs. Existing No Protection		Original Submittal
		Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	Elevation (ft)	Discharge (cfs)	
Thompson Gage	1,667,665	847.78	86782	848.93	97453	1.15	10671	1.14
Co. Hwy 25/ Co. Rd 221	1,719,816	854.00	86474	855.89	97231	1.89	10757	1.88
DS Sandhill River/ Climax	1,763,746	857.95	86221	860.01	97035	2.06	10814	2.06
Maximum Impact Location	1,782,305	859.31	82094	861.39	92696	2.08	10602	2.06
Nielsville	1,829,650	861.88	81055	863.74	91644	1.86	10588	1.87
DS Marsh River	1,864,960	863.19	80485	864.81	91190	1.62	10706	1.63
US Goose River/ Shelly	1,890,722	865.26	64673	866.48	72132	1.22	7459	1.24
Co. Rd 139	1,951,761	867.43	70727	868.25	80978	0.82	10251	0.82
Halstad Gage	1,981,580	868.71	70266	869.60	81086	0.89	10820	0.88
Hendrum	2,038,359	873.49	63579	874.41	72208	0.92	8629	0.92
Perley	2,129,181	878.15	55576	878.69	61297	0.54	5720	0.59
Georgetown	2,193,941	882.05		882.61		0.56	8101	0.67
North River/ Clay Co. Hwy 93	2,305,647	893.53		888.02		-5.51		-5.58
19th Ave N Fargo/ 28th Ave N Moorhead	2,360,321	898.98		891.53		-7.45		-7.43
Fargo Gage (13th Ave S, 12th Ave S)	2,388,223	903.00 (*40.26)		893.55 (*30.81)		-9.48	-13547	-9.46
US Rose Coulee/ US 50th Ave S Moorhead	2,430,241	906.15		896.61		-9.54		-9.52
52nd Ave S Fargo/ 60th Ave S Moorhead	2,438,085	907.01		897.27		-9.74		-9.72
US ND Wild Rice River	2,484,618	910.44		901.67		-8.77	-14176	-8.77
US Diversion	2,531,338	914.89		914.90		0.01		0.02
Hickson Gage	2,563,878	917.11	24586	917.11	24527	0.00	-59	0.01

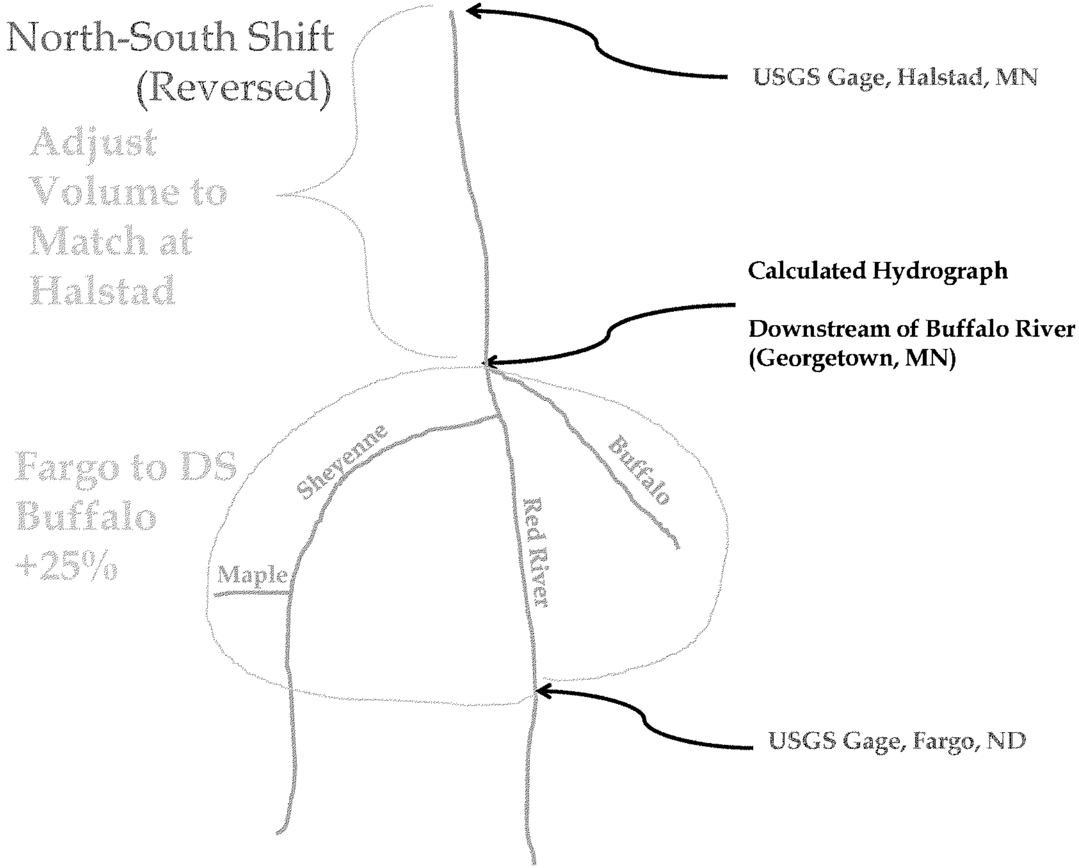
5.0 Hydrology Sensitivity



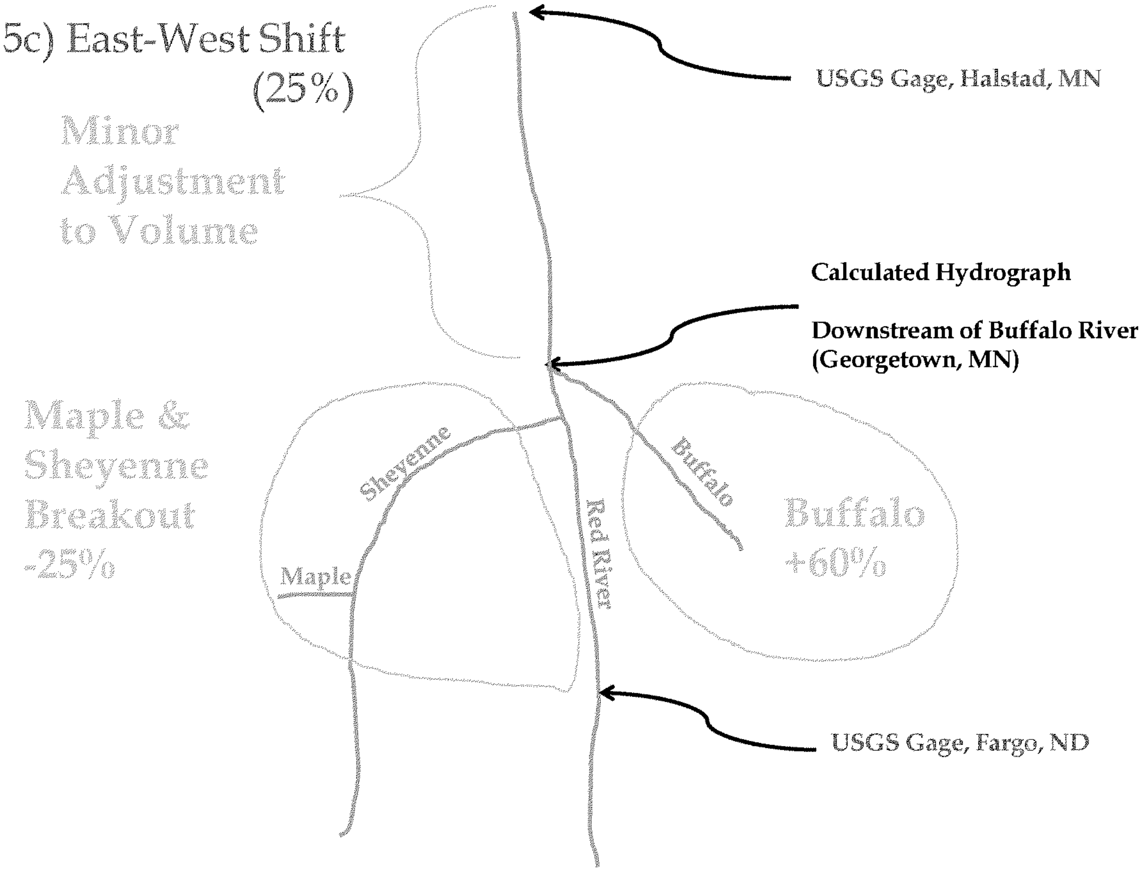
5a) North-South Shift

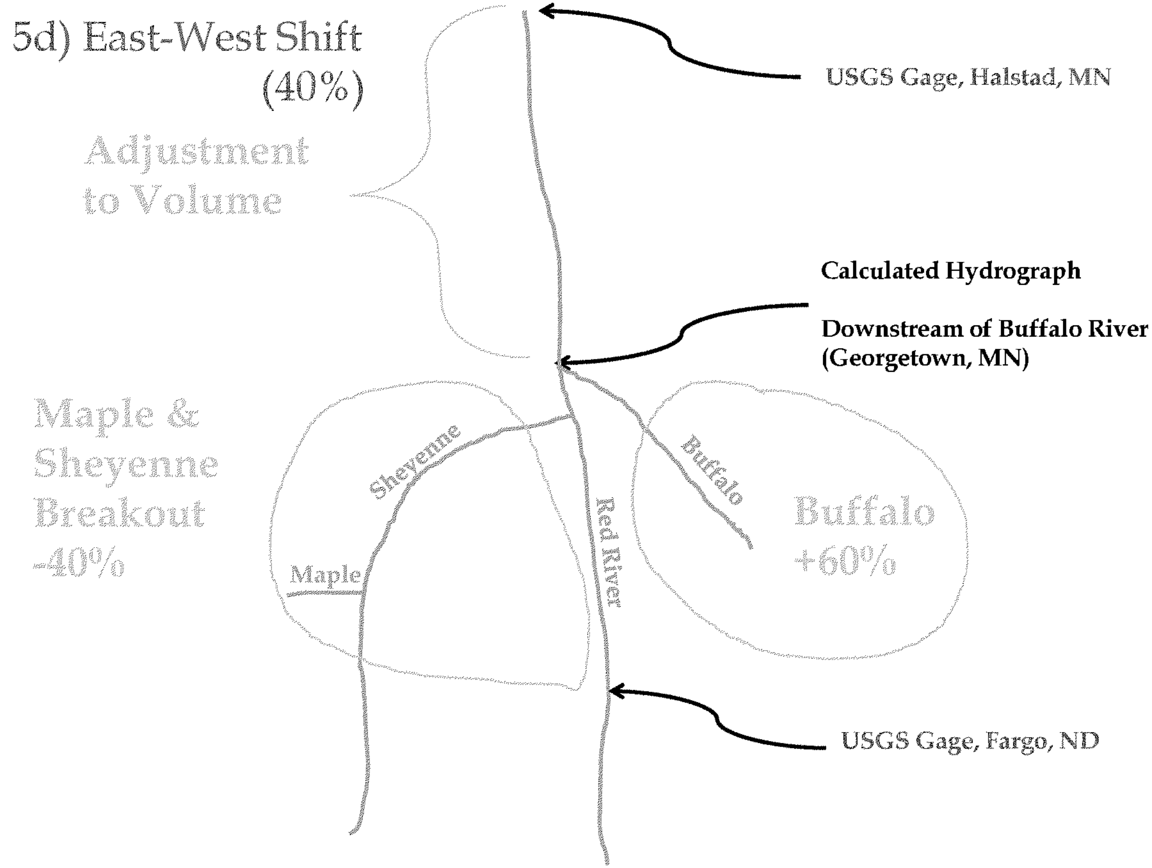


5b) North-South Shift (Reversed)



5c) East-West Shift (25%)




5d) East-West Shift
(40%)
Adjustment
to Volume
USGS Gage, Halstad, MN
Calculated Hydrograph
Downstream of Buffalo River
(Georgetown, MN)
Maple &
Sheyenne
Breakout
-40%
Sheyenne
Maple
Red River
Buffalo
Buffalo
+60%
USGS Gage, Fargo, ND

Appendix B – Hydraulics
Existing Condition

Exhibit G

Weir Coefficient Sensitivity Analysis – (Barr Engineering)

resourceful. naturally.
engineering and environmental consultants

BARR

Memorandum

To: Stu Dobberpuhl, Moore Engineering; Gregg Thielman, Houston Engineering
From: Brandon Barnes
Subject: Test runs to evaluate different model representations of flow conveyance through floodplain
Date: December 17, 2010
Project: 34/09-1004.00 400 002
c: Miguel Wong, Barr Engineering; Mark Forest, HDR Engineering; Aaron Buesing, USACE

This memorandum summarizes Barr Engineering Co. (Barr) test runs to evaluate how flow is conveyed through the Red River of the North floodplain in the HEC-RAS unsteady flow model currently being developed for the U.S. Army Corps of Engineers (USACE) Fargo-Moorhead Metro Flood Risk Management Project (henceforth referred to as the Project), Feasibility Study, Phase 4. The test runs have been conducted in support of the Consulting Team's internal peer review of the HEC-RAS unsteady flow model.

Background

HEC-RAS routes flow through storage cells using the Modified Puls Method (Storage or Level-Pool), in which the continuity equation is used but not the momentum or energy equations. Essentially the inflow, outflow, and volume stored within each storage cell are balanced. The Modified Puls Method requires an empirical relationship between outflow and storage within each storage cell to calculate the resulting water surface elevation, and such relationship accounts for free and submerged flow conditions. Application of the Modified Puls Method results in (1) assuming there is a flat water surface within each storage cell, and (2) not explicitly solving for velocity within a storage cell. This method is typically used for modeling areas of dead storage in floodplains where lateral flows are minimal and the water surface has a flat (or nearly flat) profile. However, there are locations of the HEC-RAS unsteady flow model developed for the Project study area where significant (over 5,000 cfs for the 2009 flood event) flows are conveyed through storage cells. One alternative approach (to the use of storage cells only) would be to work with cross sections that extend into the floodplain, with inline and lateral structures that may attenuate or slow passage of flows through the floodplain. The test runs presented in this memorandum allow a comparison of these two and other intermediate approaches, and they are intended to provide a preliminary evaluation of the potential influence of the floodplain routing model representation on Project design, Project benefits, and ultimately the impacts on flood levels downstream of the Project.

To: Stu Dobberpuhl, Moore Engineering; Gregg Thielman, Houston Engineering
From: Brandon Barnes
Subject: Test runs to evaluate different model representations of flow conveyance through floodplain
Date: December 17, 2010
Page: 2
Project: 34/09-1004.00 400 002

Storage Cell Review

2.5 mile reach

An approximately 2.5 mile long reach of the Wild Rice River – North Dakota was clipped out of the existing HEC-RAS unsteady flow model. This reach of river was selected because there were no lateral inflows or breakout flows to account for during the 2009 flood event, and the majority of the floodplain is contained within the model cross sections. This reach of river has been modeled here in four different ways to evaluate the flow routing through the floodplain when using storage cells only versus other possible model representations of the floodplain:

Model Representation 1. As cross sections only – All ineffective flow areas and bridge crossings were removed, as shown in Figure 1.

Model Representation 2. As cross sections only – Ineffective flow areas and blocked obstructions were added back to the model in approximately the same locations as the October 25th version of the HEC-RAS unsteady flow model of the Project study area.

Model Representation 3. As a combination of cross sections and storage areas – The channel between the bank stations was modeled as a cross section and the overbanks were modeled as storage areas, as shown in Figure 2.

Model Representation 4. As a combination of cross sections and storage areas – The channel between the bank stations was modeled as a cross section and the overbanks were modeled as storage areas. In two intermediate locations, cross sections were extended across the entire floodplain to control flow and water surface elevation in the storage areas, as shown in Figure 3.

Each of the four models was run with three different peak flows: (1) a low flow condition where the flow is primarily contained within the banks of the channel (5,600 cfs), (2) a medium flow condition where flow starts to overtop the banks (9,800 cfs), and (3) the peak flow of the 2009 flood hydrograph (14,000 cfs).

The upstream and downstream boundary conditions were the same for all four model representations. The upstream boundary condition for each model was the inflow hydrograph. For each model representation the inflow hydrograph was placed at a cross section that extended across the entire floodplain at the upstream end of the reach. The downstream boundary condition for each model was normal depth, where HEC-RAS uses Manning's equation to calculate a stage for each computed flow. The friction slope entered as the downstream boundary condition was the approximate slope of the channel near the downstream end of the reach. (This downstream boundary condition could be changed to one based on the downstream rating curve, but the assumption made here does not invalidate the comparison of results for the four model representations.)

The Manning's n values used for all four model representations were selected based on the Manning's n values along the Wild Rice River used in the October 25, 2010 version of the HEC-RAS model. Manning's n values for the channel and overbanks were set at 0.045 and 0.08 respectively. During calibration of the HEC-RAS model to observed events the overbank Manning's values were increased to 0.09-0.13. The Manning's values were not revised for this analysis, which is intended to provide a relative comparison of different model representations of flow routing through the floodplain.

Figures 4-9 show that the change in model representation of routing through the floodplain does not have an appreciable impact on the shape of the flood hydrograph at the downstream end of this 2.5 mile reach. However, modeling the entire reach with storage cells (i.e., model representation 3 and 4) accelerates the peak flow by a couple of hours compared to the cross section models (i.e., model representation 1). This shift of a couple of hours over a 2.5 mile reach might prove to be significant over a longer reach, as changes on both magnitude and timing are important in determining impacts downstream of the Project diversion channel outlet into the Red River of the North.

Water surface profiles along the entire reach of river included in this analysis have been also compared. Water surface profiles for the models with cross sections (i.e., model representations 1 and 2) have a distinct slope, with an overall drop in water surface elevation of 1.4-1.8 ft. In comparison, the model that utilize storage areas (i.e., model representation 3) appear to convey flows more efficiently, and only has a drop in water surface elevation of 0.1-0.3 ft over the reach of river modeled. Water in the storage cell model is allowed to equalize through all of the storage cells, which translates into a relatively flat water surface throughout the entire model. Finally, cross sections were extended across the floodplain to control the flow through the overbank storage cells (i.e., model representation 4). The water surface profile resulting from this model representation has a slope in the sections modeled with cross sections, and level pools in the areas modeled with storage areas (see Figures 10-12).

16 mile reach

To check the impact of a longer reach, an approximately 16 mile reach of the Wild Rice River – North Dakota was clipped out of the existing HEC-RAS unsteady flow model. This reach of river has been modeled here in six different ways to evaluate the flow routing through the floodplain when using storage cells only versus other possible model representations of the floodplain:

Model Representation 1.	As cross sections only – All ineffective flow areas and bridge crossings were removed, as shown in Figure 13. The overbank Manning's n values were set at 0.08
Model Representation 1a.	As cross sections only – All ineffective flow areas and bridge crossings were removed, as shown in Figure 13. The overbank Manning's n values were set at 0.05.

Model Representation 2. As a combination of cross sections and storage areas – The channel between the bank stations was modeled as a cross section and the overbanks were modeled as storage areas, as shown in Figure 14. All discharge coefficients for storage areas and lateral connections were kept at the default values of 3.0 for storage connections and 2.0 for lateral structures.

Model Representation 3. As a combination of cross sections and storage areas – The channel between the bank stations was modeled as a cross section and the overbanks were modeled as storage areas – except the discharge coefficients were all reduced to 1.0 for storage area connections as well as lateral structures.

Model Representation 4. As a combination of cross sections and storage areas - The channel between the bank stations was modeled as a cross section and the overbanks were modeled as storage areas. In four intermediate locations a cross section was extended across the entire floodplain to control flow and water surface elevation in the storage areas, as shown in Figure 15. All discharge coefficients for storage area connections and lateral connections were kept at the default values of 3.0 for storage areas and 2.0 for lateral structures.

Model Representation 5. As a combination of cross sections and storage areas - The channel between the bank stations was modeled as a cross section and the overbanks were modeled as storage areas. In four intermediate locations a cross section was extended across the entire floodplain to control flow and water surface elevation in the storage areas, as shown in Figure 15. All discharge coefficients for storage area connections and lateral connections were reduced to 1.0.

Each of the six models was run with three different peak flows: (1) a low flow condition where the flow is primarily contained within the banks of the channel (5,600 cfs), (2) a medium flow condition where flow starts to overtop the banks (9,800 cfs), and (3) the peak flow of the 2009 flood hydrograph (14,000 cfs). For areas where the floodplain extended beyond the extents of the cross section or storage cells, vertical walls were put in the model to prevent breakout flows. In addition, no tributary inflows were accounted for in this analysis to simplify the modeling effort, which is intended to provide a relative comparison of different model representations of flow routing through the floodplain.

The upstream and downstream boundary conditions were the same for all six model representations. The upstream boundary condition for each model was the inflow hydrograph. For each model representation the inflow hydrograph was placed at a cross section that extended across the entire floodplain at the upstream end of the reach. The downstream boundary condition for each model was normal depth, where HEC-RAS uses Manning's equation to calculate a stage for each computed flow. The friction slope entered as the downstream boundary condition was the approximate slope of the channel near the downstream end of the reach. (This downstream boundary condition could be changed to one based on the downstream rating curve, but the assumption made here does not invalidate the comparison of results for the six model representations.)

The Manning's n values used for all six model representations were selected based on the Manning's n values along the Wild Rice River used in the October 25, 2010 version of the HEC-RAS model. Manning's n values for the channel and overbanks were set at 0.045 and 0.08 respectively. During calibration of the HEC-RAS model to observed events the overbank Manning's values were increased to 0.09-0.13. To evaluate the impact of lowering the overbank Manning's value Model Representation 1a was run with lower Manning's values. The Manning's values were not revised for this analysis to match the current calibrated HEC-RAS model, rather this analysis is intended to provide a relative comparison of different model representations of flow routing through the floodplain.

Figures 16-21 show that the change in model representation of the floodplain does have an impact on the shape of the flood hydrograph at the downstream end of this approximately 16 mile reach. Modeling the overbanks with storage cells and the HEC-RAS default discharge coefficients for the storage area connections and lateral structures (i.e., model representation 2) accelerates the peak flow by 13-19 hours compared to the cross section model (i.e., model representation 1). When the discharge coefficients are lowered for the lateral structures (from 2.0 to 1.0) and storage area connections (from 3.0 to 1.0) (i.e., model representation 3), the shift in timing is reduced to 8-11 hours. If the discharge coefficients are left at their default values, but cross sections are periodically extended across the floodplain (i.e., model representation 4), the shift in timing is 8-12 hours. Finally, if the discharge coefficients are reduced to 1.0 in combination with extending cross sections across the floodplain (i.e., model representation 5), the shift in timing is reduced to 1-6 hours. Table 1 includes a summary of how the hydrograph peak is accelerated as the methodology used to model flow through the floodplain changes.

Table 1. Acceleration in Hydrograph Peak Compared to the Cross Section Only Model

Model	14,000 cfs Peak Flow Rate	9,800 cfs Peak Flow Rate	5,600 cfs Peak Flow Rate
Model Representation 1. Cross Sections Only (Overbank Manning's values of 0.08)	-	-	-
Model Representation 1a. Cross Sections Only (Overbank Manning's values of 0.05)	5 hours	4 hours	2 hours
Model Representation 2. Storage Areas in Overbanks (default discharge coefficients for lateral structures and storage connections)	19 hours	17 hours	13 hours
Model Representation 3. Storage Areas in Overbanks (discharge coefficients for lateral structures and storage area connections of 1.0)	11 hours	11 hours	8 hours
Model Representation 4. Storage Areas in Overbanks with Cross Section Extending Across the Floodplain Approximately every 4 miles (default discharge coefficients for lateral structures and storage connections)	12 hours	11 hours	8 hours
Model Representation 5. Storage Areas in Overbanks with Cross Section Extending Across the Floodplain Approximately every 4 miles (discharge coefficients for lateral structures and storage area connections of 1.0)	1 hour	4 hours	6 hours

In general, as shown in Figures 16, 18, and 20 the change in model representation of flow routing through the floodplain results in a shift in timing for the overall hydrograph at the downstream end of the model of this 16 mile reach.

Water surface profiles along the entire reach of river included in this analysis were also compared. Water surface profiles for the cross section model (i.e., model representation 1) has a distinct slope, with an overall drop in water surface elevation of 19.4-18.5 ft. In comparison, the models that utilize storage areas appear to convey flows more efficiently, and have less of a drop in water surface elevation over the reach modeled (approximately 1.0-2.5 ft less). Table 2 summarizes these results.

Table 2. Drop in Water Surface Elevation through 16 Mile Reach

Model	14,000 cfs Peak Flow Rate	9,800 cfs Peak Flow Rate	5,600 cfs Peak Flow Rate
Model Representation 1. Cross Sections Only (Overbank Manning's values of 0.08)	18.5 ft	19.1 ft	19.4 ft
Model Representation 1a. Cross Sections Only (Overbank Manning's values of 0.05)	18.7 ft	19.3 ft	19.5
Model Representation 2. Storage Areas in Overbanks (default discharge coefficients for lateral structures and storage connections)	16.3 ft	17.4 ft	18.3 ft
Model Representation 3. Storage Areas in Overbanks (discharge coefficients for lateral structures and storage connections of 1.0)	18.1 ft	18.7 ft	19.0 ft
Model Representation 4. Storage Areas in Overbanks with Cross Section Extending Across the Floodplain Approximately every 4 miles	16.7 ft	17.7 ft	18.6 ft
Model Representation 5. Storage Areas in Overbanks with Cross Section Extending Across the Floodplain Approximately every 4 miles (discharge coefficients for lateral structures and storage area connections of 1.0)	18.2 ft	18.9 ft	19.1 ft

Water in the storage cell models is equalized through adjacent storage cells resulting in a flatter water surface throughout the entire model, as shown in Figures 17, 19, and 21. This result could explain why during the calibration effort of the HEC-RAS unsteady flow model for the Project study area, modeled elevations are lower than observed elevations for some locations.

Summary

With respect to the HEC-RAS unsteady flow model for the Project study area, the results of the test runs presented here could suggest that in locations where large amounts of flow are being conveyed through storage cells (e.g., south of the Maple River, Drain 40 east of the Sheyenne River, in the overbanks of the Red River of the North of the confluence with the Buffalo) the modeled water surface profiles might be too flat. More importantly, the model representation of the floodplain in terms of storage cells only, with

HEC-RAS default values used for the discharge coefficients of the storage area connections and lateral structures, could be resulting in flood flows being routed downstream more efficiently (hydraulically speaking) than warranted. The resulting shift in timing could have an impact on evaluation of downstream impacts, even though both Existing Conditions and With-Project unsteady HEC-RAS models use similar methodologies to represent how flow is conveyed through the floodplain.

The test runs presented are set up to demonstrate sensitivity to how the floodplain is modeled. Model sensitivity for the Project unsteady model may vary as the size and location of storage areas vary compared both to the test runs completed and throughout the unsteady model developed for the Project. None of the test runs presented includes obstructions in the floodplain such as road crossings which may alter the sensitivity of the conveyance capacity in the floodplain when comparing different modeling methodologies.

One potential way to model how quickly water is conveyed through the storage cells could be to periodically extend a cross section across the entire floodplain. However, this may not be practical throughout the domain of the HEC-RAS unsteady flow model developed for the Project study area. Another way to potentially slow down flow through the floodplain is to use lower (than the HEC-RAS default values) discharge coefficients for the storage area connections and lateral structures. For the 16 mile reach, a discharge coefficient of less than 1.0 could be required for storage area connections and lateral structures if the goal is to slow down the hydrograph so that model results are comparable to the same reach modeled with only cross sections.

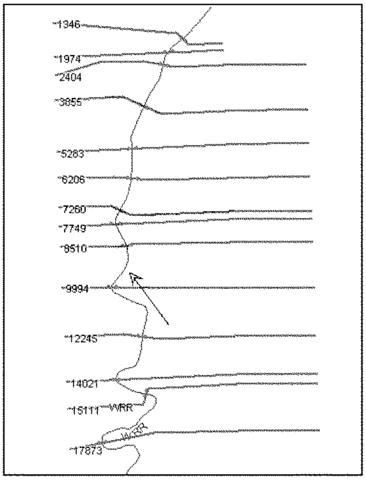


Figure 1. Section of Wild Rice River (2.5 mile) – North Dakota modeled with cross sections only. Geometry for Model Representation 1 and 2

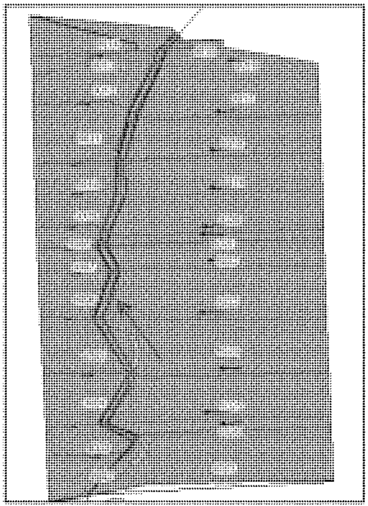


Figure 2. Section of Wild Rice River (2.5 mile) – North Dakota modeled with cross sections between the bank stations and storage areas for the overbanks. The geometry for each storage area connection is taken from the cross section geometry used in the first model. Geometry for Model Representation 3.

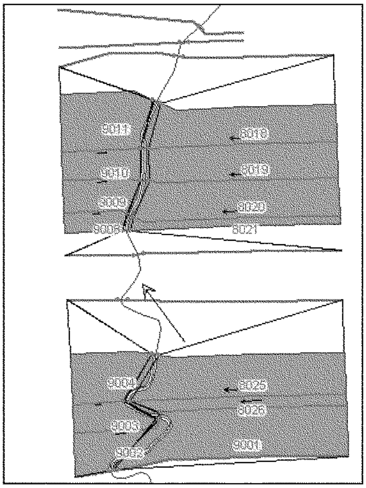


Figure 3. Section of Wild Rice River (2.5 mile) – North Dakota modeled with cross sections between the bank stations, storage areas for the overbanks, and two locations where cross sections extend across the floodplain. The geometry for each storage area connection is taken from the cross section geometry used in the first model. Geometry for Model Representation 4.

Figure 4. Peak Flow of 5,600 cfs for 2.5 Mile Reach

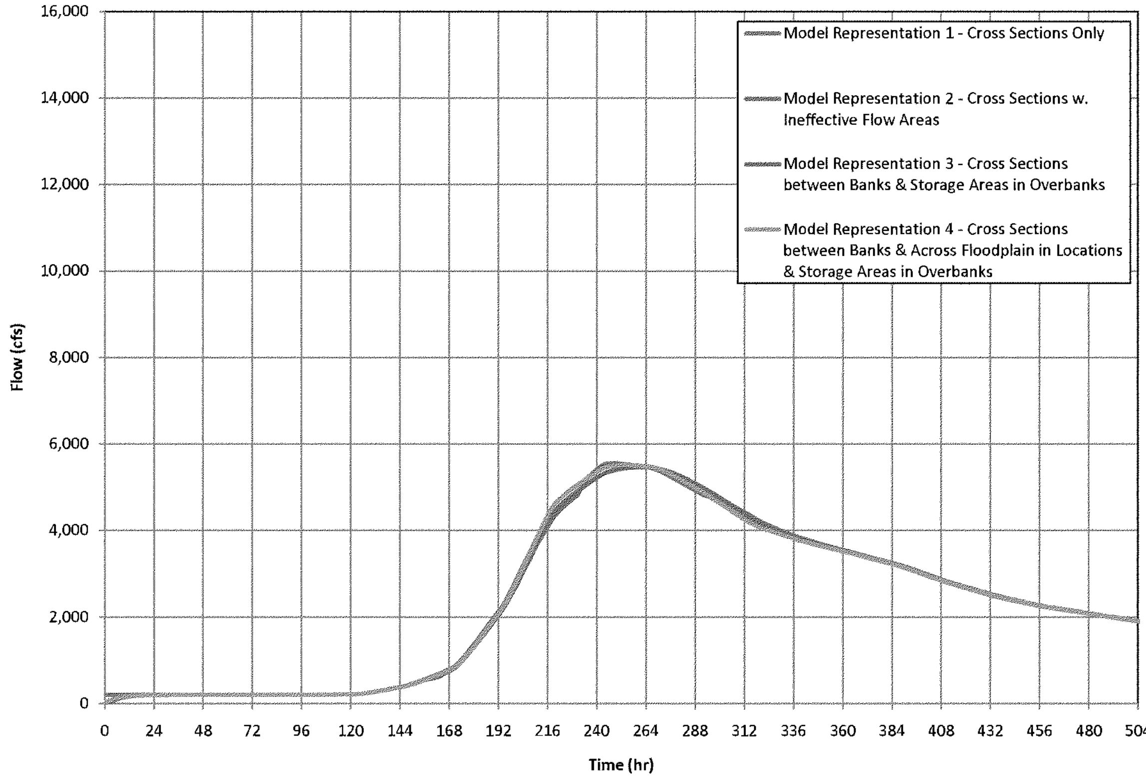


Figure 5. Peak Flow of 5,600 cfs (Peak only) for 2.5 Mile Reach

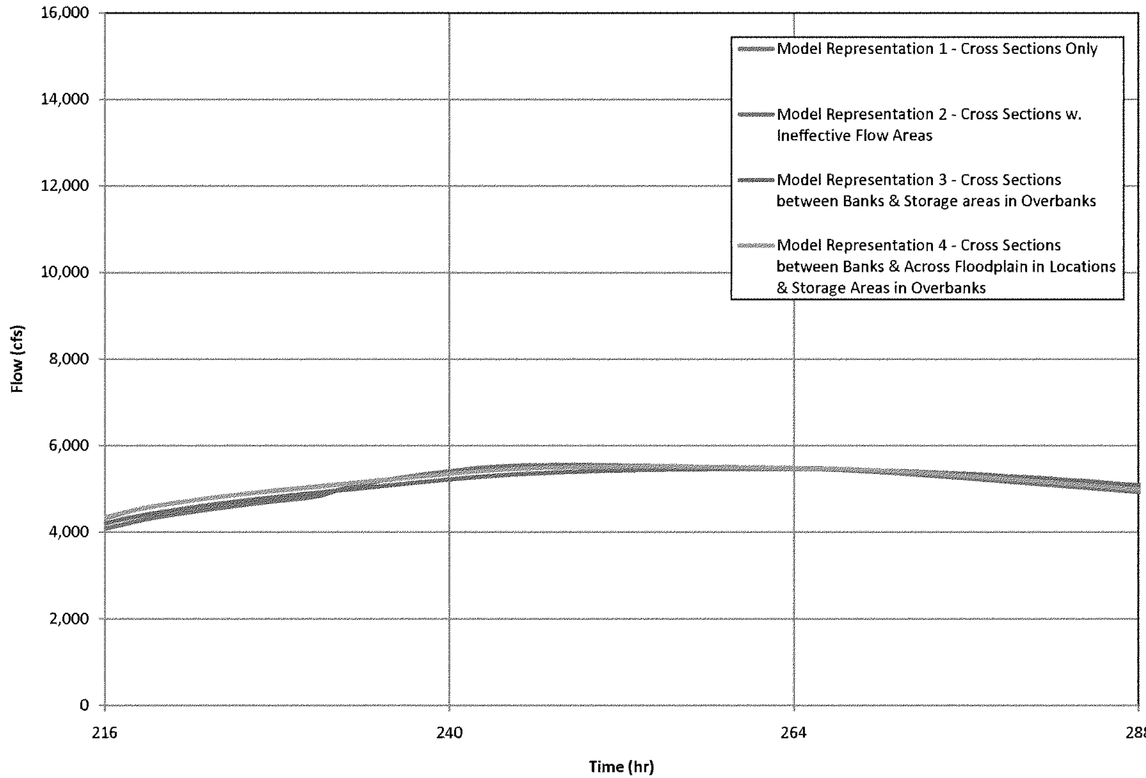


Figure 6. Peak Flow of 9,800 cfs for 2.5 Mile Reach

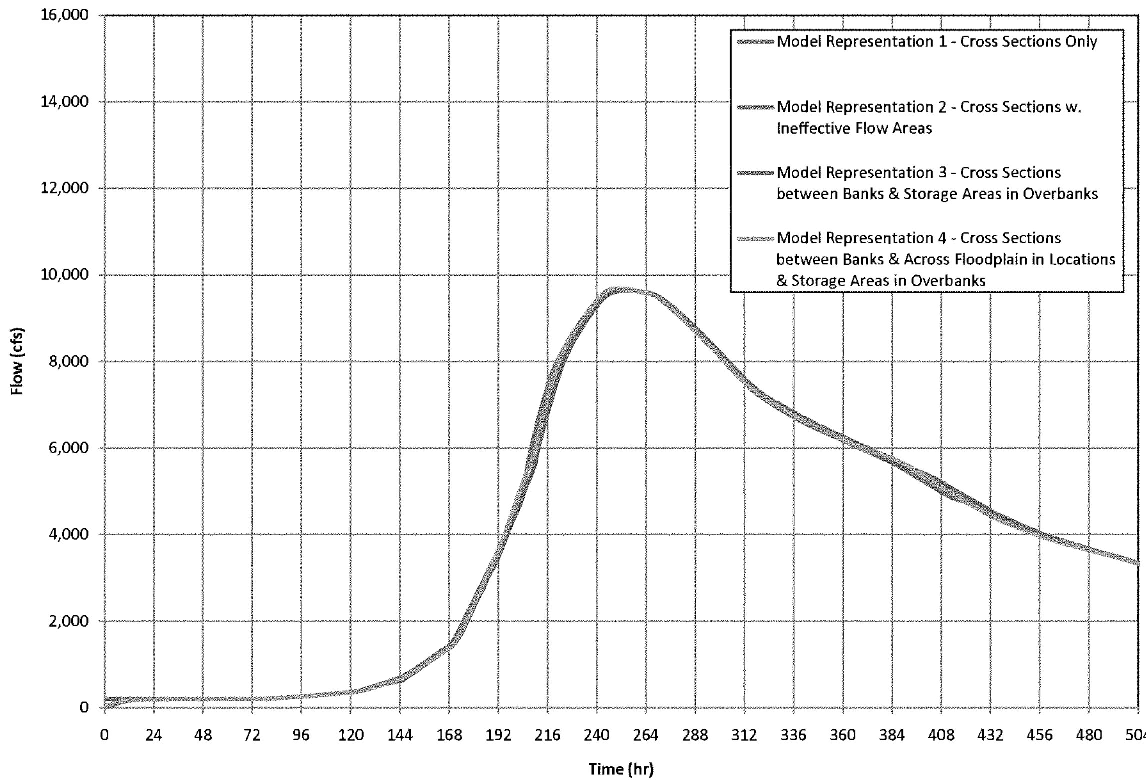


Figure 7. Peak Flow of 9,800 cfs (Peak only) for 2.5 Mile Reach

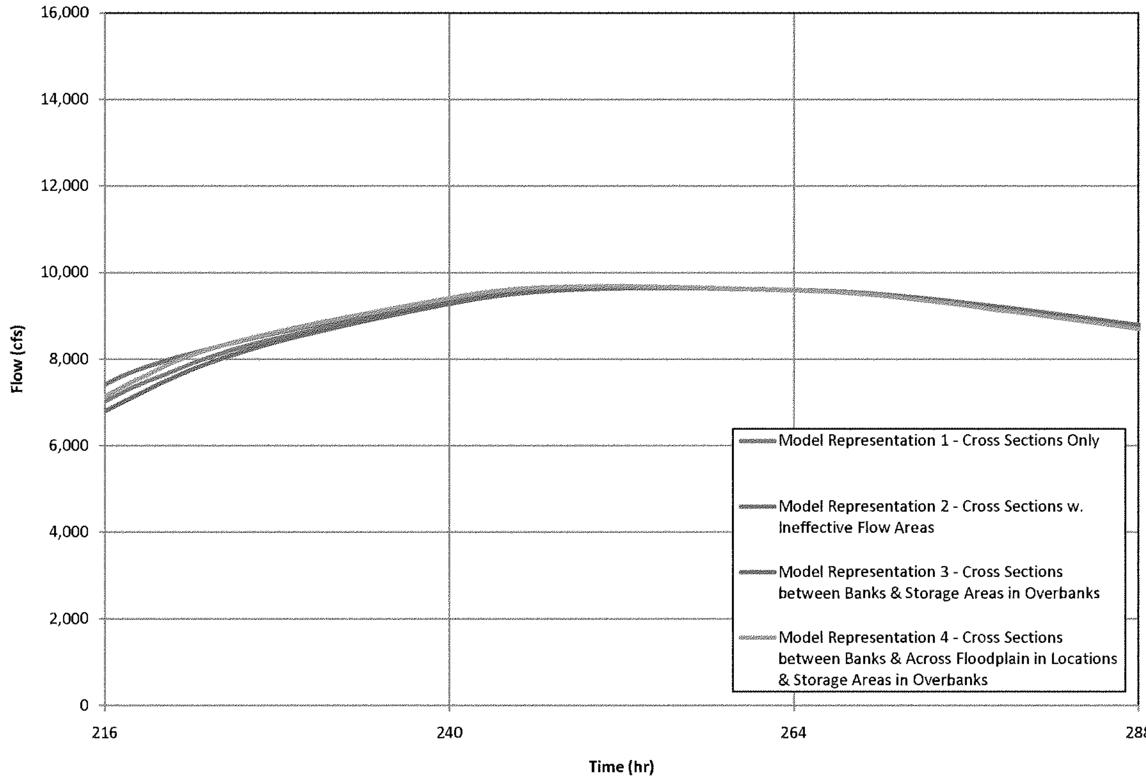


Figure 8. Peak Flow of 14,000 cfs for 2.5 Mile Reach

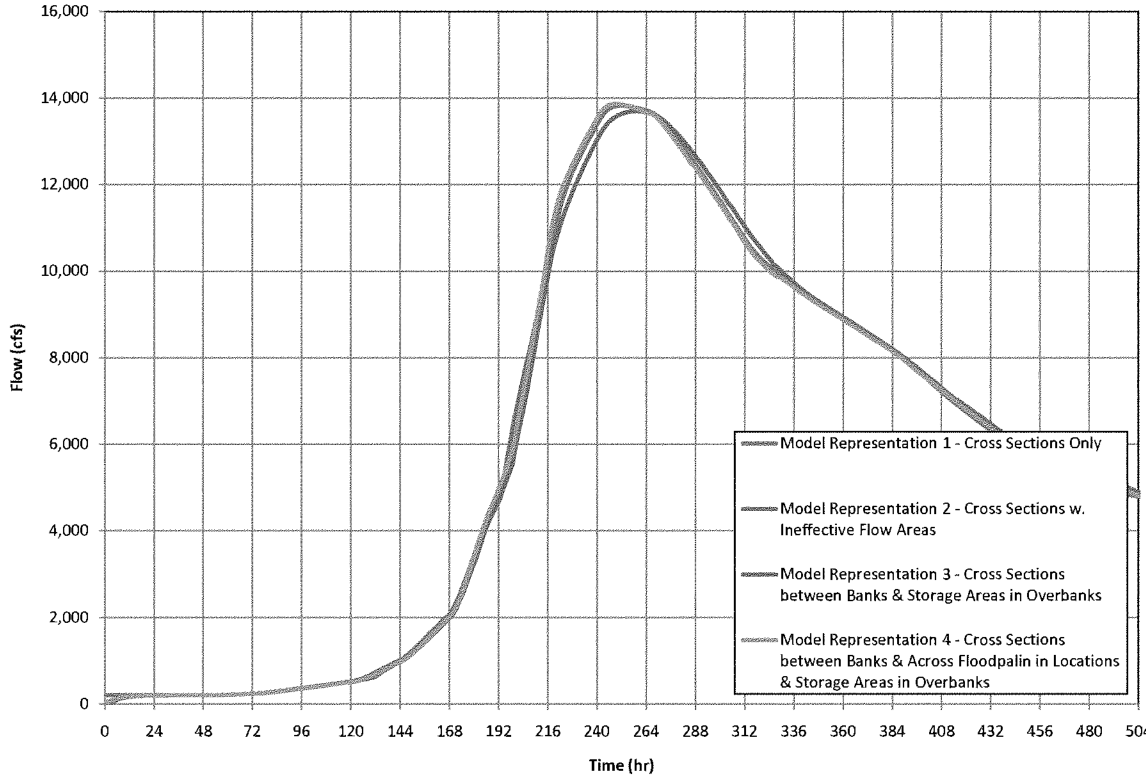


Figure 9. Peak Flow of 14,000 cfs (Peak only) for 2.5 Mile Reach

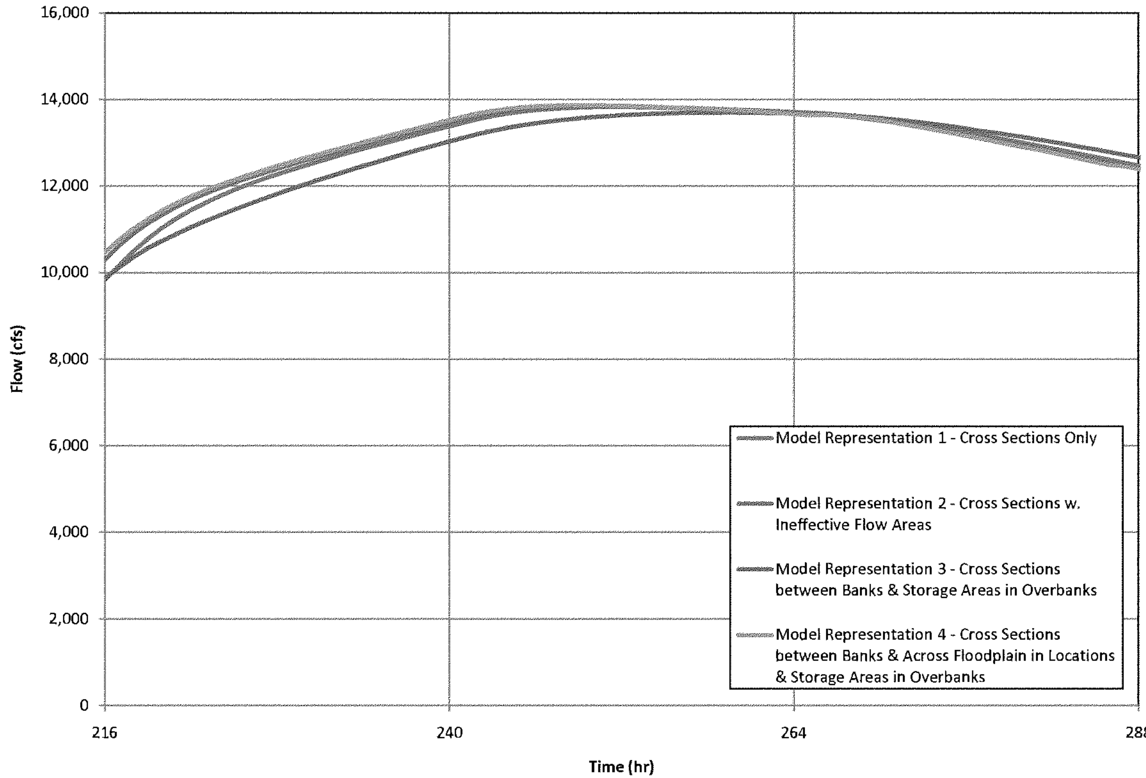
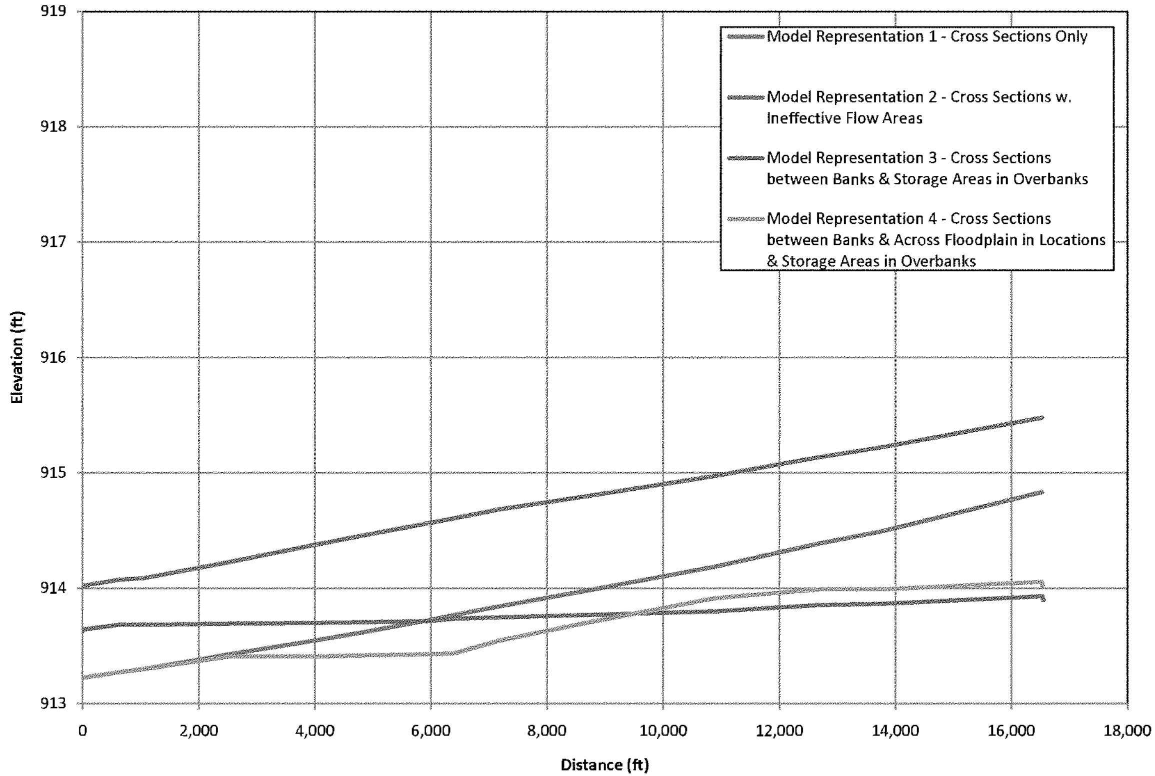


Figure 10. Water Surface Profile - 5,600 cfs



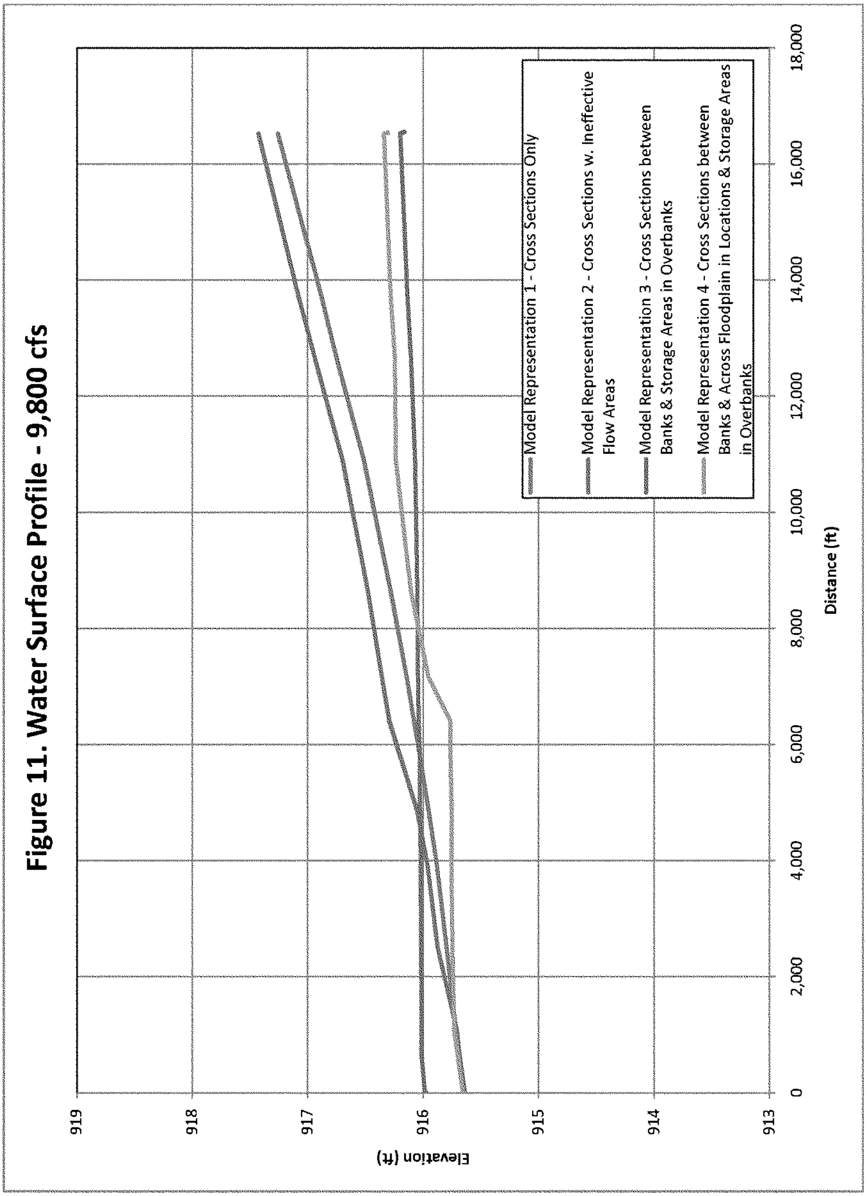
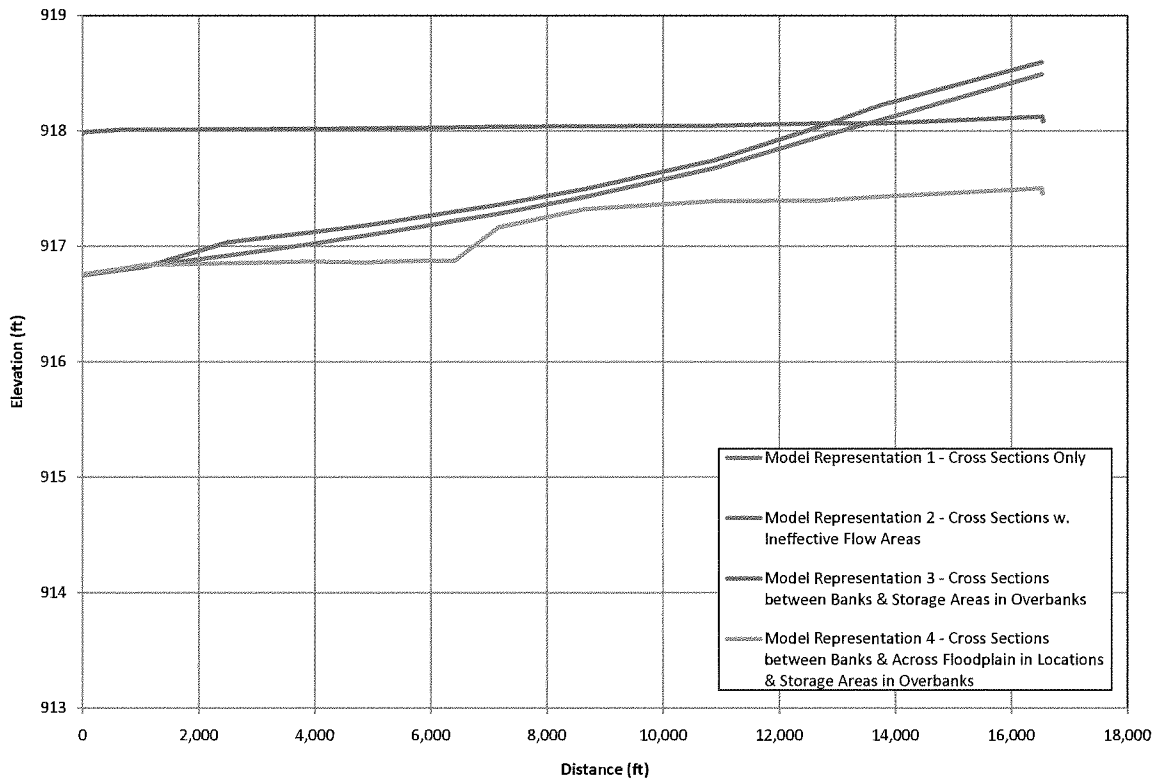


Figure 11. Water Surface Profile - 9,800 cfs
Elevation (ft)
919
918
917
916
915
914
913
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
Distance (ft)
Model Representation 1 - Cross Sections Only
Model Representation 2 - Cross Sections w. Ineffective Flow Areas
Model Representation 3 - Cross Sections between Banks & Storage Areas in Overbanks
Model Representation 4 - Cross Sections between Banks & Across Floodplain in Locations & Storage Areas in Overbanks

Figure 12. Water Surface Profile - 14,000 cfs



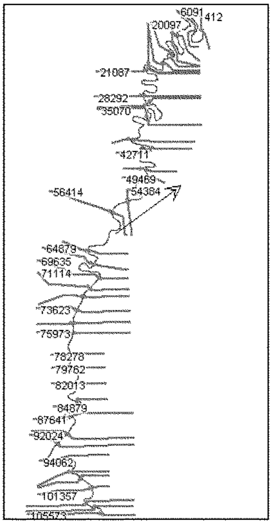


Figure 13. Section of Wild Rice River (16 mile) – North Dakota modeled with cross sections only. Geometry for Model Representation 1 and 1a.

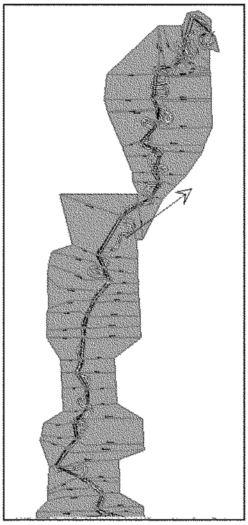


Figure 14. Section of Wild Rice River (16 mile) – North Dakota modeled with cross sections for the bank stations and storage areas in the overbanks. Geometry for Model Representation 2 and 3.

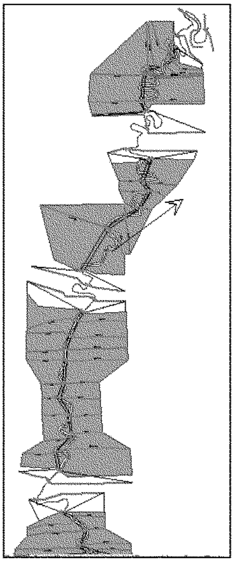


Figure 15. Section of Wild Rice River (16 mile) – North Dakota modeled with cross sections between the bank stations, storage areas for the overbanks, and four locations where cross sections extend across the floodplain. The geometry for each storage area connection is taken from the cross section geometry used in the first model. Geometry for Model Representation 4 and 5.

Figure 16. Peak Flow of 14,000 cfs for 16 Mile Reach

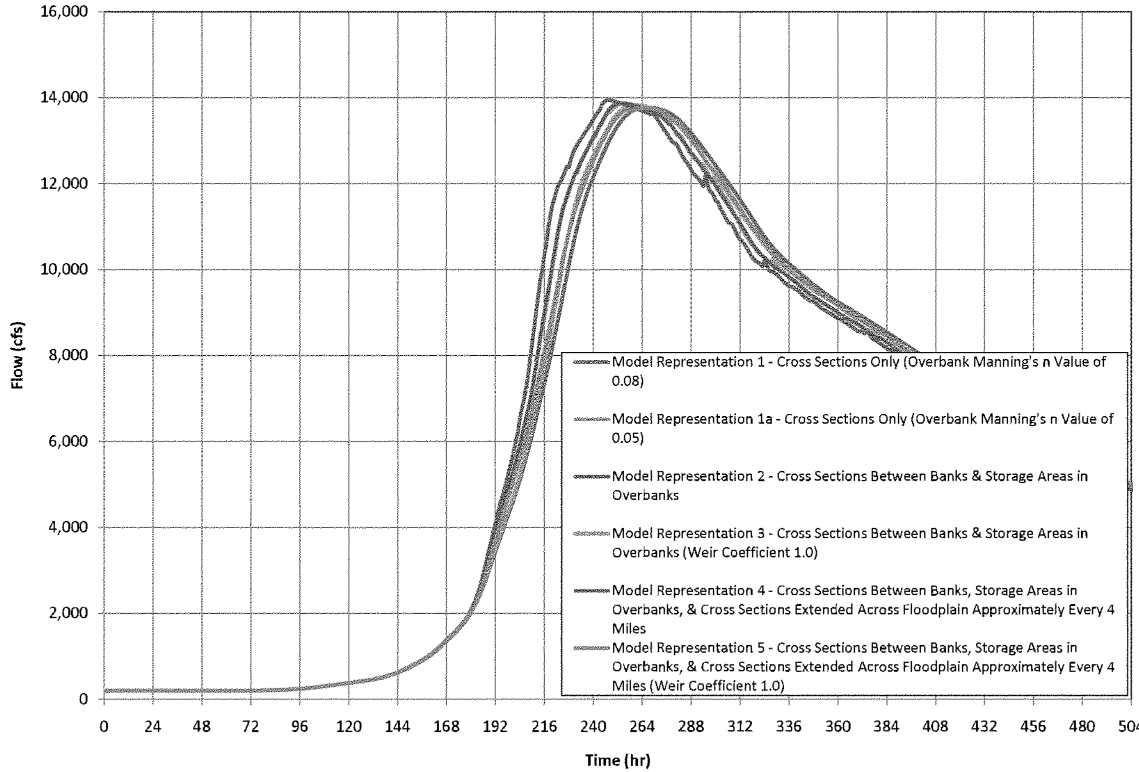
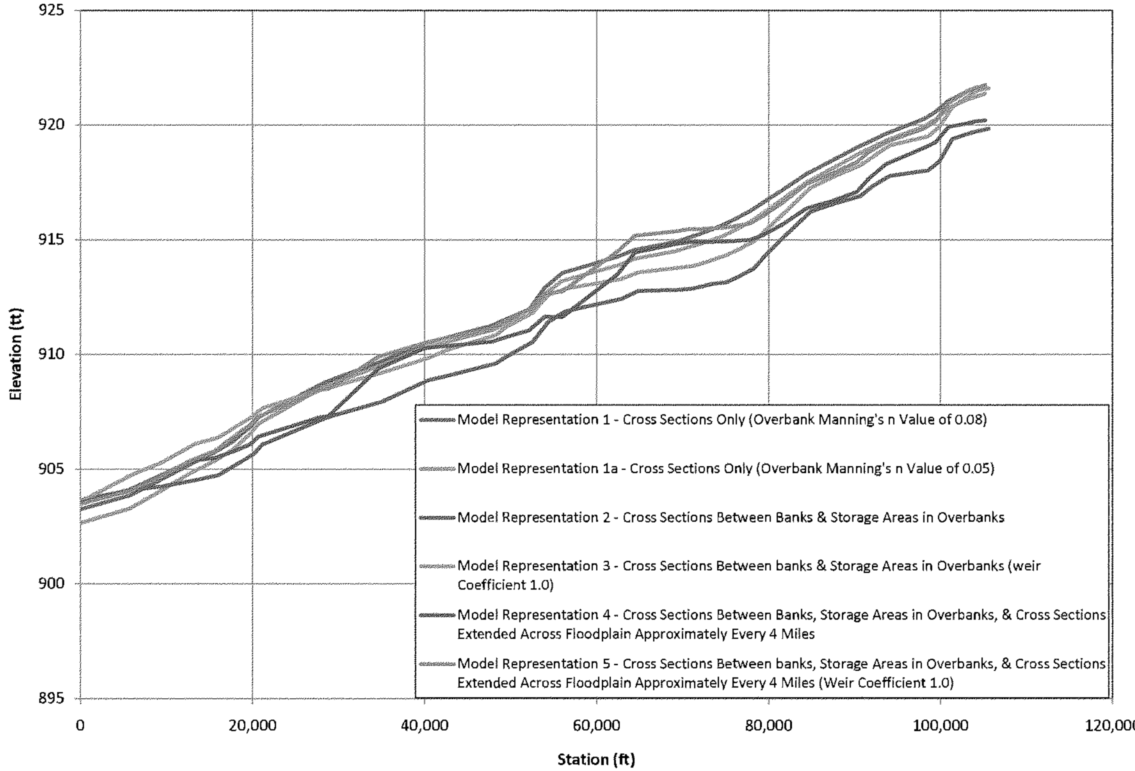


Figure 17. Water Surface Profile for 16 mile section of River- 14,000 cfs



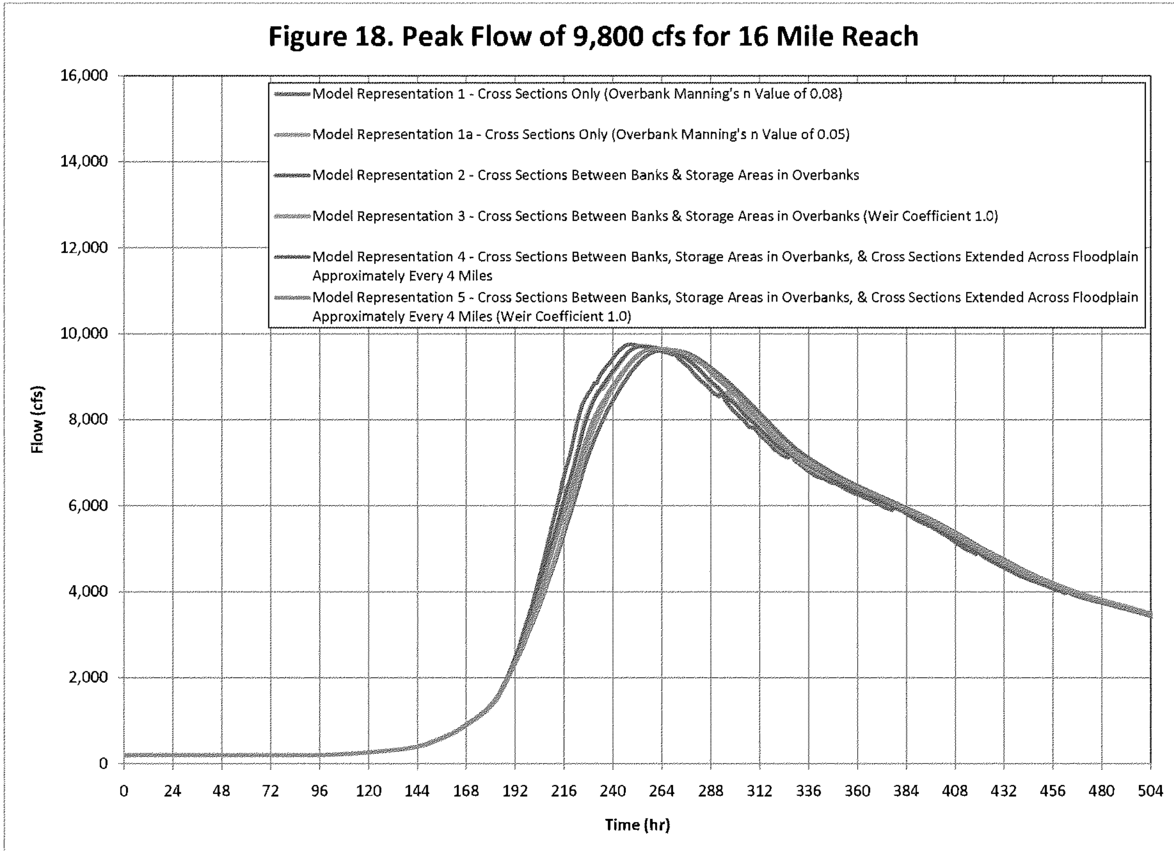


Figure 18. Peak Flow of 9,800 cfs for 16 Mile Reach
Model Representation 1 - Cross Sections Only (Overbank Manning's n Value of 0.08)
Model Representation 1a - Cross Sections Only (Overbank Manning's n Value of 0.05)
Model Representation 2 - Cross Sections Between Banks & Storage Areas in Overbanks
Model Representation 3 - Cross Sections Between Banks & Storage Areas in Overbanks (Weir Coefficient 1.0)
Model Representation 4 - Cross Sections Between Banks, Storage Areas in Overbanks, & Cross Sections Extended Across Floodplain Approximately Every 4 Miles
Model Representation 5 - Cross Sections Between Banks, Storage Areas in Overbanks, & Cross Sections Extended Across Floodplain Approximately Every 4 Miles (Weir Coefficient 1.0)
Flow (cfs)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0 24 48 72 96 120 144 168 192 216 240 264 288 312 336 360 384 408 432 456 480 504
Time (hr)

Figure 19. Water Surface Profile for 16 mile section of River- 9,800 cfs

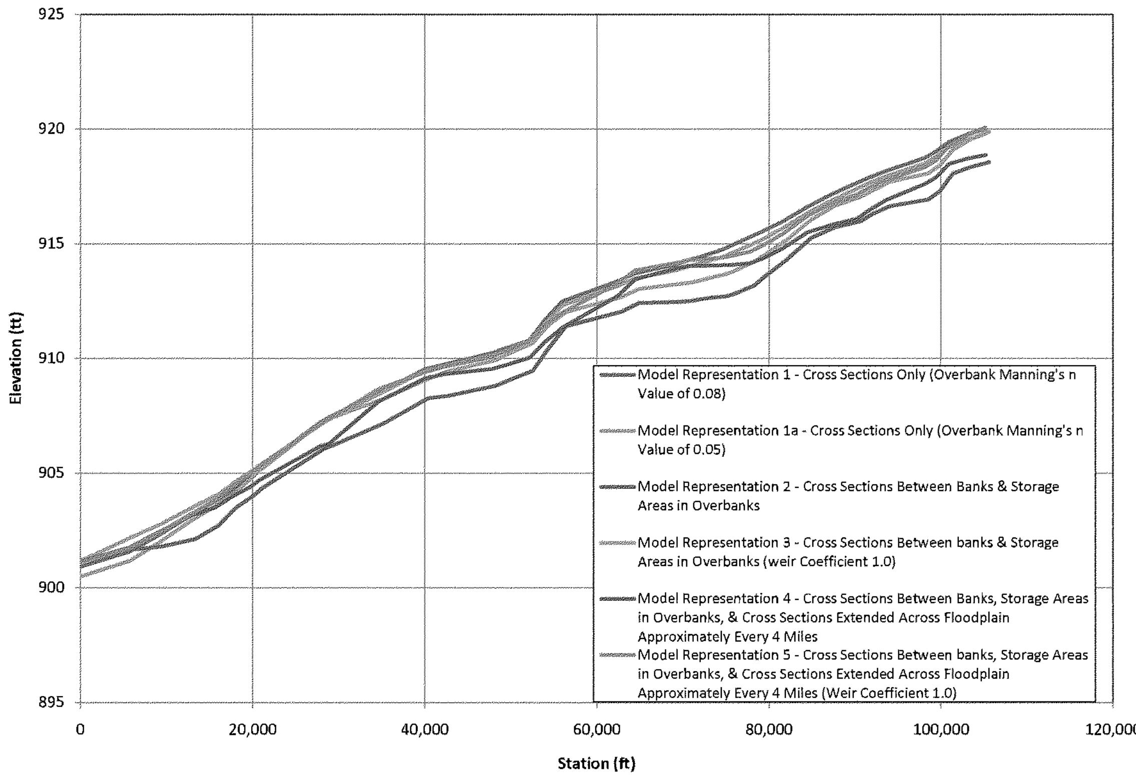


Figure 20. Peak Flow of 5,600 cfs for 16 Mile Reach

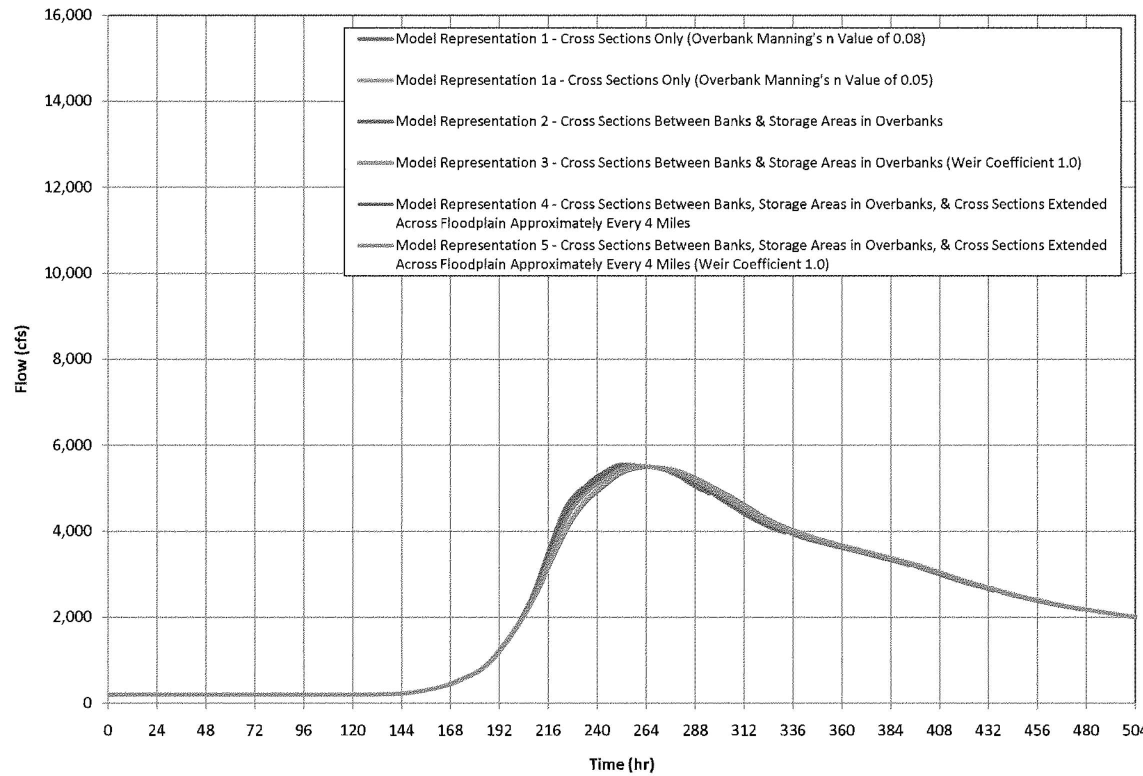
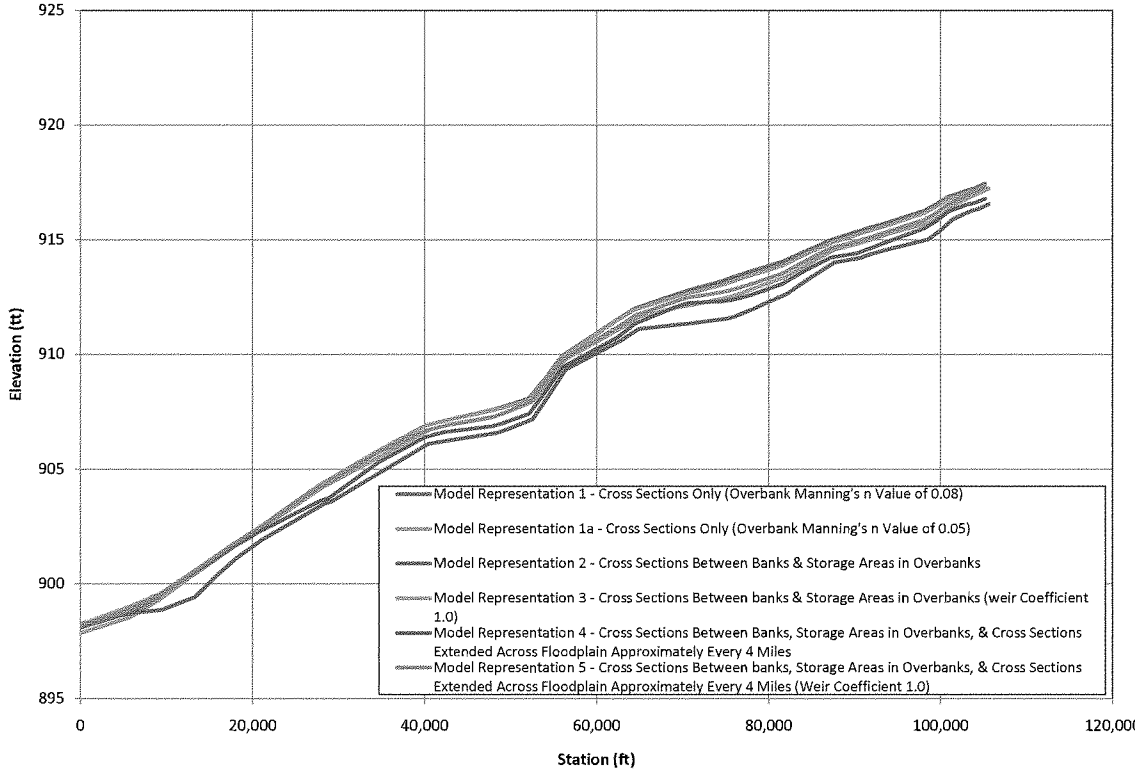


Figure 21. Water Surface Profile for 16 mile section of River- 5,600 cfs



Appendix B – Hydraulics
Existing Condition

Exhibit H

Model Peer Review and Model QA/QC Measures

RED RIVER DIVERSION

FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4

APPENDIX B – HYDRAULICS EXISTING CONDITIONS EXHIBIT H – MODEL PEER REVIEW AND MODEL QA/QC MEASURES

Report for the US Army Corps of Engineers, and the cities of Fargo, ND & Moorhead, MN

By: HOUSTON ENGINEERING, INC.

FINAL: February 28, 2011

TABLE OF CONTENTS

1. GENERAL

Developing a model as large and complex as the one created for this project it is of the best interest of the project team, sponsors and US Army Corps of Engineers to have reviews completed to help build the best model and end product. Several internal reviews as well as external an agency reviews were conducted. Many of the comments have been addressed with responses during closure of previous phases of this project. Three reviews were conducted as part of Phase 4. One preliminary internal to the project team review was completed by Moore Engineering, Inc. Another detailed technical review was conducted by Barr Engineering. The third review was a broad, general review completed by HDR. The following sections outline our response to the review comments. Copies of the actual comments are also included with this Exhibit.

2. REVIEWS

2.1 Review 1. Preliminary Internal Review by Moore Engineering, Inc.

The comments provided by Moore Engineering, Inc. were provided while the 2009 Calibration model was being developed. Since the comments were provided early in the model development process, many of them have been incorporated into the final models submitted in Phase 4.

Responses

1. **Cross Section Spacing** – The model geometry was obtained from previous models. Additional cross sections had not yet been added. In response to this comment, additional cross sections were added to the Hickson to Thompson reach of the Red River. Cross sections were added to the extent possible while maintaining perpendicular flow paths through a large, meandering channel and broad floodplain. Additional cross sections should still be added to the Thompson through Drayton reach of the Red River.
2. **2009 Calibration for Next Phase of Modeling** – Matching stage at the Fargo gage and through the protected area was rather challenging. The modeled water surface elevations were generally lower than observed data. Many parameters were adjusted through internal sensitivity analyses in attempt of increasing stage. The final outcome was to maintain a channel "n" value of 0.045. One possible contribution to the higher stages at the lower discharges is the uncertainty of the discharge measurements. Often times field measurements are not available prior to the flood wave progressing downstream. Discharges were lowered in upstream hydrographs to help this situation. The stage and calibration through the Fargo/Moorhead area will continually be addressed in future models.
3. **Weighted Manning's "n" Values** – Generally, the unsteady state model has manning's "n" values on the upper end of accepted values. The particular cross sections referred to in this comment had horizontally varying "n" value errors. They have since been fixed.
4. **XS Delta WS Values** – See response to comment 1. Cross sections have been added.

5. **Manning's "n" Values** – See response to comment 3. Horizontally varied "n" values were fixed.
6. **Channel Bank Locations** – Considerable review and sensitivity iterations were conducted to best simplify the complex flow paths of the Red River into a 1-D model. The bank stations define where overbank flow is compared to channel flow. This defines conveyance areas as well as flow path reach lengths. Aerial photos were used for the 2009 flood to best estimate conveyance area and overbank vs. channel reach lengths.
7. **Correction Hydrograph** – In that version of the calibration, the model matched the hydrograph at Halstad, MN. Routing this hydrograph downstream provided excessive discharges at Thompson without accounting for any local inflows. A conversation with the USGS supplied additional information on what actually occurred during the flood. The field measurements were rated poor and we were advised by the USGS to ignore the values at Halstad and use Thompson instead. The correction hydrograph was removed and the model results at Halstad were not considered for comparison.
8. **Junctions** – The downstream reach lengths were set at zero in case this may double count volumes.
9. **Lateral Weir Profiles** – Moore Engineering provided new storage area connections based on the interstate ramps and Jersey barriers.
10. **Lateral Structure (LS 1658177)** – Additional cross sections were added as part of comment 1 that also addresses this comment.
11. **Flow Roughness Factors** – The flow roughness factors were applied in an attempt to lower the stages at lower flows. This seemed to be addressed as the base flow discharges were lowered. It still may be a manning's "n" value issue to be addressed with comment 2 in the future.
12. **Sheyenne River Breakout** – The reviewed version of the model had very limited detail in this area. Since then, additional detail has been added, however, details as specific as this are difficult to address with a model as complex and as large as this. Stages in the Sheyenne River Area are difficult to adequately match, especially with the quality of the observed data.
13. See Response to 12.
14. The control structure was later added with plan data.
15. The observed hydrograph was moved to the correct location.
16. This hydrograph calibration at this location has since been discontinued. Instead calibration was maintained at the USGS gages, Fargo and Halstad.

2.2 Review 2. Internal Review by Barr Engineering

The comments provided by Barr Engineering were completed after the preliminary 2009 Calibration model was developed. This was intended to be a detailed review of the model geometry, flow files and results. Many of the comments addressed details in non-detailed reaches in the model which do not impact to the objective of the model.

Responses

1. Version 4.1

2. NAVD 88
3. It is in the Phase 4 submittal
4. NAD 83, UTM 14N FOOT_US
5. Feet from stream mouth
6. Agreed.
7. Agreed.
8. No.
9. Cross sections overlap where tributaries meet with the Red River. The Red River cross sections have been created such that their conveyance is consistant through the junction. The tributary cross sections are in place to route the lower tributary flows to the Red River. Additional volume storage caused by overlapping cross sections was assumed to be minimal.
10. Agreed.
11. Agreed.
12. Agreed.
13. Yes. However, a shorter run time produces output with less iteration.
14. Agreed.
15. Model iterates significantly with tighter tolerances.
16. Agreed.
17. Agreed.
18. Agreed.
19. Agreed.
20. Rating Curve
21. Yes, See Exhibit E. Cross section hydrograph output cannot be compared to balanced hydrograph in model. The cross section only represents a portion of the flow. Depending on the location, additional conveyance is added in storage area connections.
22. Agreed.
23. No.
24. In the model that was reviewed, the Wolverton local inflow hydrograph was placed at the upper boundary condition of the stream. When the hydrology was applied, the hydrograph would flow downstream in the channel and it would also flow backwards into the empty storage area. Since then, the hydrograph was applied to the storage area which took care of this issue. Negative flows through Oakport are expected. They are breakout flows from the Red River and will be negative.
25. This is difficult to tell with 12 hour hydrograph output ordinates.
26. Agreed.
27. Yes. Breakouts, Reverse flow due to flood wave on Red River backing into stream reaches. Ex. Sheyenne River, Rose Coulee.
28. Agreed.
29. Yes. See Appendices A, B, C, D for Historic comparisons to USGS gages, and Appendix E for synthetic comparisons to balanced hydrographs.
30. Agreed.
31. Agreed.

32. Reviewed to some extent. It is a large and complex model. Not everything could be addressed with the given schedule.
33. No.
34. n/a
35. Rating Curve based on field measurements on the Red River from USGS Gage 05092000 at Drayton, ND.
36. Much of the examples given were situations where geometry was created with LiDAR only. See Table B1 of Appendix B.
37. The Sheyenne River is a perched channel. Therefore, there are significant breakouts that often times transfer flow out of the localized system. The effective flood insurance study model discharges for the 2-, 1-, and 0.2-percent chance events are all nearly the same on the Sheyenne River. Similar discharges will provide similar water surface profiles and increase the likelyhood of the profiles crossing. Drain 34 was a reach with limited detail. Water surface profiles should be used evaluated with caution.
38. No.
39. No. However, significant detail in floodplain mapping has taken place.
40. Not Checked.
41. Not Checked.
42. HEC-RAS Manual
43. Yes. Table B2 in Appendix B provides a list of the Manning's "n" values used.
44. Agreed.
45. Unsteady flow model parameters are all set to zero. Okay.
46. Additional cross sections were added to the Red River reach between Hickson and Thompson. The Thompson to Drayton reach could be improved with additional cross sections in the future.
47. Yes. Primarily for stability in some locations.
48. 1000 feet is relatively a short distance on the Red River given the dimensions of the channel meander.
49. No. However, most seem to be reasonable.
50. Agreed.
51. Agreed.
52. Agreed.
53. Drains 27 and 53 are small tributary reaches. They have spoil banks on each side. The cross sections are extended beyond the spoil banks, but conveyance is contained in the channel.
54. Consider the majority of the noted river reaches are routing reaches. Also, the Sheyenne River is a perched channel where the water surface will likely be close to the bank stations at full channel capacity.
55. Some locations.
56. Not in routing reaches. See Table B1 of the Appendix B report
57. Not all bridges were checked due to the size and complexity of the model
58. Not checked at all locations.
59. Dependent on source data as explained in Table B1 of the Appendix B report.

60. Most Lateral structure and storage connection weir coefficients are 1. Some were reduced to 0.5 to help reduce iterations where low crossings provided too much flow. Inline structures were set at 2.6.
61. Levees are typically roads or temporary or permanent flood protection. The WSEL on WRRND RS 169582 does go above the cross section plot on the left end, however that portion of the cross section does not convey water (ineffective flow)
62. To the extent possible. Complex model.
63. To the extent possible. Complex model.
64. Reasonable widths.
65. To the extent possible. Complex model.
66. To the extent possible. Complex model.
67. To the extent possible. Complex model.
68. Agreed.
69. Agreed.
70. Agreed.
71. Cross sections width will vary between cross sections in meanders vs. straight reaches. Also, some reaches are for routing purposes and have been created with less detail. The majority of the specifically noted distances are in the RLR to Drayton reach (Red Lake River to Drayton). This reach was primarily used as received with minor modifications for calibration. Additional cross sectios were not created.
72. Not checked.
73. Not revised. Minor issue. Drain 37 is routing reach.
74. Not revised. Minor issue. Drain 37 is routing reach.
75. Cross Section was a sensitivity check and was supposed to be removed. It is now removed.
76. Not revised. Complex model. Could be reviewed in the future. Storage area drains out from initial condition.
77. Not revised. Complex model. Could be reviewed in the future. Initial condition attenuates before flood wave begins.
78. As expected. Similar to the Red River and Rose Coulee.
79. This may be related to the connection with the Sheyenne Diversion Reach and the Inlet structure to the Sheyenne Diversion. It does carry downstream, but is still 7-8 days before the primary flood wave passes through.

2.3 Review 3. Internal Review by HDR

HDR provided comments on the Existing Conditions models prior to the January 31, 2011 submittal. HDR has expanded the previous comments to address the With-Project LPP comments. These were provided on February 25, 2011. The review by HDR addresses larger scale model structure, stability and data fit to observed data.

Responses

1. Table B1 was supplied with the January 31, 2011 submittal that presents the sources of the HEC-RAS geometry data and level of detail and quality of such data.
2. General comment, no response required.
3. General comment, no response required.
4. General comment, no response required.
5. General comment, no response required.
6. It is not likely that the bridge modeling approach will changed for specific event frequencies with separate geometries. It is a complex model many bridges. Additional effort would be required to evaluate the modeling approach of each bridge.
7. The model was developed using model geometry from previous studies. The cross section layout was complete. Additional cross sections were added through the Hickson to Thompson reach on the Red River. During calibration, aerial photos were used to assist in setting ineffective flow locations and elevations.
8. Considerable review and sensitivity iterations were conducted to best simplify the complex flow paths of the Red River in a 1-D model. The bank stations define where overbank flow is compared to channel flow. This defines conveyance areas as well as flow path reach lengths. Aerial photos were used for the 2009 flood to best estimate conveyance area and overbank vs. channel reach lengths. Additionally, the location and number of channel points limit the options for where the bank stations are placed because a bank station has to be placed on a specific channel point. Without adding an arbitrary point to the cross section, the bank station may be slightly higher or lower on one cross section or another. Bank stations through the detailed portion of the Red River (upstream of Halstad) seem fairly consistent. Additional detail should be added to the Halstad to Drayton reach as part of future modeling efforts.
9. Increasing the maximum iterations to 40 may improve the model. However a sensitivity analysis was conducted to test this. Actually, a similar number of maximum iteration locations appear during unsteady flow computations. As expected, the model run time is significantly longer. Model stability was found to improve with a decreased computation time step.
10. The cross section was inserted as a sensitivity analysis and it has now been removed. Matching stage at the Fargo gage and through the protected area was rather challenging. The modeled water surface elevations were generally lower than observed data. Many parameters were adjusted through internal sensitivity analyses in attempt of increasing stage. The final outcome was to maintain a channel "n" value of 0.045.
11. Cross sections overlap where tributaries join with the Red River. The tributaries often approach the Red River at an angle. The Red River cross sections have been created such that their conveyance is maintained through the junction. The tributary cross sections are in place to route the lower tributary flows to the Red River. The tributaries are relatively small in comparison to the Red River. Additional volume storage caused by overlapping cross sections was assumed to be minimal. This appears to be an issue. However, no solution or suggestion was provided as an alternative by the review or project team.

12. In response to this comment, the model was revised to have weir coefficients of 1 for storage area connections and lateral structures as discussed in Section 3.5.3 of Appendix B.
13. Modifying the inflow hydrographs would impact the modeled stages recorded and likely provide a different calibration fit to observed data. Some gage analysis was completed and it appears as though the rating curve is adjusted based on the loop. Additional investigation into this would be beneficial.
14. Aerial photos were used in calibration of the 2009 ad 1997 flood events. The flood inundation extents match the aerial photos reasonably well.
15. The high water marks were obtained through field survey. The data is considered to be reliable. The river conditions such as wave action, local turbulence, gradients caused by velocity were not known when the survey was conducted. Additional detail could be placed on the specific bridges with regard to contraction/expansion.
16. The 2009 flood event had an initial crest and then in some locations experienced a second one. The calibration focused on the first crest and less emphasis on matching the second crest.
17. General comment, no response required.
18. Will consult with USGS again for further information on looped rating curve at Fargo.
19. Will consult with USGS again for further information on looped rating curve at Hickson.
20. The observed hydrograph was an estimate provided by USACE. It is anticipated that the process to development the estimated hydrograph did not have a method of accounting for model geometry storage and routing.
21. Observed stream gage data was obtained from the USGS website. A gage at this location was not available. If there is a stream gage here, it is anticipated that backwater from the Red River would cause issues due to its close proximity to the Red River.
22. Stream gage stage records on the Sheyenne River have heavy influence from ice conditions and breakout discharges. This can also be identified by the rating curve irregularity from the stream gage.
23. The reach can be added again as part of future modeling efforts.
24. The Harwood stream gage has a water impact from the Red River. This is the reason discharges are not calculated here.
25. Cass County Drain 14 conveys local inflow hydrograph water as well as possible breakout water. Inflows entered into the system represent a 104 square mile drainage area that extends upstream to the Sheyenne River and downstream to the confluence of Drain 14 with the Maple River. This inflow should be uniformly distributed.
26. The sources of inflow hydrographs are provided in the February 28, 2011 Appedix B.
27. The HTAB parameter has been fixed.
28. The lateral structure should be fixed as part of future modeling efforts.
29. The geometry was obtained from another project. It will be reviewed during future modeling efforts.

30. The channel bottom on Drain 34 was estimated.
31. Cross sections could be deleted. This is a routing reach only.
32. Elm River is a routing reach.
33. Could add cross sections as part of future modeling efforts.
34. General comment, no response required.
35. Drain 37 is a routing reach with little detail.
36. Inundation limits were compared to aerial photos. They match well.
37. General comment, no response required.
38. General comment, no response required.
39. The observed balanced hydrographs were compared in previous phases. However, now in Phase 4, storage areas were added and some cross sections were shortened to convey the same flow. Reviewing results at specific cross sections only represents part of the transect flow since additional water is conveyed in the storage areas and connections. A direct comparison would not be accurate.
40. Hydrograph comparisons are provided in Exhibit E of Appendix B.
41. The levees match current permanent flood protection through Grand Forks. Distances in the model on the referenced cross section on Figure 23 were verified with distances shown on the aerial images from the 2009 flood event. They are the same. The referenced model cross section in Figure 24 is not the cross section pointed at in the aerial image of Figure 24. The levee shown in the center of the image is the levee protecting Grand Forks, however the reviewer is pointing at the levee on the east side of East Grand Forks that protects the City from the Red Lake River.

REVIEW 1. PRELIMINARY INTERNAL REVIEW BY MOORE ENGINEERING, INC.

FARGO MOORHEAD METRO FEASIBILITY STUDY

UNSTEADY FLOW MODELING - Initial Review Prior to Calibration of the 2009 Event

COMMENTS/RESPONSE 10-28-2010

Reviewer	Org	Review Type	#	Date of Comment	Comments
MEI	MEI	Internal	1	28-Oct-2010	**Cross-section spacing.** In 4 instances, the cross-section spacing is greater than 4 miles and in 108 instances the sections are spaced over 1 mile apart. Consideration should be given to adding additional cross-sections or at least to determining how sensitive the spacing is for the downstream impact analysis. See **Table 1** for a list of sections where the spacing is greater than 1 mile. A spacing of more than 1/3 mile can be pushing the limit for cross-section spacing. In particular, the cross-section spacing upstream and downstream of a lateral structure could be even more sensitive. In the case of the lateral structure that transfer flow to Heartsville Coulee, the spacing is 18,976 feet (see comment 10 on this lateral structure).
MEI	MEI	Internal	2	28-Oct-2010	**2009 Calibration for Next Phase of Modeling.** At RS 2,388,223, a plot showing a comparison of computed versus observed elevations shows a significant difference for flows less than about 14,000 cfs. See **Figure 1**. It is realized that at this stage the model calibration is not calibrated. However, the differences in stage are quite large. This indicates that the "n" values are high for the low flow channel. When the calibration of the model is accomplished, the goal should be to obtain as good a calibration as possible for even low flows.
MEI	MEI	Internal	3	28-Oct-2010	**Weighted Manning's "n" Values.** Plots of weighted Manning's "n" values for the channel as shown in **Figure 2** show that the channel n values are extremely high. It is typical for reviewers to look at this plot to judge the reasonableness of "n" values. It appears only *some* of these "n" values are just merely shifted (i.e., Red River RS 2,316,206 and 2,415,915 and 2,416,271) Note that Table 2 does not pick up all of the sections with n values issues as illustrated by RS 2,416,271.
MEI	MEI	Internal	4	28-Oct-2010	**XS Delta WS Values.** A plot (**Figure 3**) of the change in water surface elevations indicates that some of the changes in water surface elevations are quite large. Consideration should be given to adding cross-sections where the difference is large.
MEI	MEI	Internal	5	28-Oct-2010	**Manning's "n" Values.** The range of "n" values for just the channel portion of the RRN Sections was reviewed. Some of the sections have n values which are outside the normal range. **See Table 2.**
MEI	MEI	Internal	6	28-Oct-2010	**Channel Bank Locations.** The location of the bank stations has been identified previously in the ATR comments dated 10-5-1010 for the unsteady flow model (comment 18). In additional to this the steady flow model had received ATR comments stating that the channel bank stations needed to be brought down in elevation to the primary bank stations. These comments were followed and a good calibration for the entire rating curve at the Fargo Gage was achieved (for both low and high flows). This provided for a reasonable channel "n" value, which may help to address comments 3 and 5. Consideration should be given to address this issue, and not just for the reach below the Thompson gage (but also from Hickson through Fargo to the Thompson gage).
MEI	MEI	Internal	7	28-Oct-2010	**Correction Hydrograph.** A large negative correction hydrograph in the Red River SH to RLR reach indicates a problem with either the calibration discharge hydrograph on the main stem or else the input hydrographs for the tributaries. See Figure 4.
MEI	MEI	Internal	8	28-Oct-2010	**Junctions.** The distance across a junction is being applied twice, which will result in the energy losses calculated by the model twice. This is due to having the distance across the junction in (a) the junction editor and (b) the last downstream cross section of the river upstream of the junction. To correct this issue the distance entered into the last downstream cross section of the river upstream of the junction should be zero.

REVIEW 1. PRELIMINARY INTERNAL REVIEW BY MOORE ENGINEERING, INC.

FARGO MOORHEAD METRO FEASIBILITY STUDY					
UNSTEADY FLOW MODELING - Initial Review Prior to Calibration of the 2009 Event					
COMMENTS/RESPONSE 10-28-2010					
Reviewer	Org	Review Type	#	Date of Comment	Comments
MEI	MEI	Internal	9	28-Oct-2010	**Lateral Weir Profiles.** The lateral weir profiles for storage area connections "FgoSC131" and "FgoSC128" are not representative of the actual highest ground elevation available. These storage area connections represent Interstate-94 west of the Red River in Fargo. This is critical since nearly 9,400 cfs is currently being modeled over I-94 for the 100-year event (peak discharge), with a WSEL of 904.12 at the I-94 bridge. Two issues are identified at this location. The first is that "FgoSC131" should be drawn over the north ramp (west bound) at the 25th Street South crossing, *not* the south ramp (east bound). This will result in a 'lowest road profile' from a current elevation of approximately 902 to approximately 906. "FgoSC128" between 25th Street South and University Drive does not seem to be drawn over the highest available ground elevation over I-94. Identifying the highest ground profile over I-94 would result in a 'lowest road profile' from an elevation of approximately 903 to approximately 904. The second and maybe most crucial feature would be the New Jersey Style road barriers along I-94. These are approximately 3 feet above the road profile. This may control the amount of flow that breaks out of the Red River and flows over I-94. The controlling profile over I-94 needs to be identified and incorporated into the geometry of the model.
MEI	MEI	Internal	10	28-Oct-2010	**Lateral Structure (LS 1,658,177).** There is an extremely long distance between "Red River - WRRMN to RLR" RS's 1,667,665 and 1,648,688, which is 3.6 miles long (18,946.38 feet). This results in 2.54 feet of energy losses for the maximum water surface profile. To compound the matter, there is a lateral structure (LS 1,658,177) between these two cross sections representing breakout flow into Heartsville Coulee. Additional cross sections should be added within this area to properly model the energy equation and the breakout flow into Heartsville Coulee.
MEI	MEI	Internal	11	28-Oct-2010	**Flow Roughness Factors (100-Year).** The "Flow Roughness Factors" are not consistent from reach to reach with the set of flow range values.
MEI	MEI	Internal	12	28-Oct-2010	**Sheyenne River Breakout.** The 2009 calibration currently has breakout flow west of the Sheyenne River near Cass Hwy 14 near Horace. The model currently shows 1,790 cfs flowing through MSHSC338 as lateral wier flow, which represents the railroad profile. This railroad profile does not contain the wooden bridge over Drain 21C. Consideration should be given to modeling this storage area connection as a 'weir and culvert' to ensure sufficient backwater from the railroad embankment is provided. This may help to resolve the issue identified in comment 13.
MEI	MEI	Internal	13	28-Oct-2010	**Sheyenne River Breakout.** The 2009 calibration currently has breakout flow west of the Sheyenne River near Cass Hwy 14 near Horace. The model currently shows 1,780 cfs flowing over Cass Hwy 14 on MSHSC402 as lateral weir flow. According to County Hwy personel this road was never overtopped in 2009, although it did get come up to the road shoulder.
MEI	MEI	Internal	14	28-Oct-2010	**Sheyenne River.** The 2009 calibration geometry does not contain the control structure at the Horace to West Fargo Diversion inlet. Rather, only a rating curve is applied to pull water into the Horace to West Fargo Diversion. Consideration should be given to modeling the box culverts at the control structure, which will impact the amount of water into the protected area of Horace and West Fargo.
MEI	MEI	Internal	15	28-Oct-2010	**Wild Rice River Hydrograph.** An observed hydrograph is currently at RS 169,892, which is upstream of I-29. The correct location of this HOBO data should be at RS 166,766, which is just downstream of the current location, at Richland Hwy 2.
MEI	MEI	Internal	16	28-Oct-2010	**Intermediate Calculated Flow Hydrograph for RRN nr Georgetown.** In the responses to the ATR comments, the discussions address the flow calibration for the RRN at Georgetown. Since this location does not have observed flow data, the overall flow calibration should match the locations where there is observed USGS flow data. The HEC-RAS model should not be **forced** to fit the intermediate calculated flow hydrograph if it is developed by hydrologic techniques.
NOTE: THE COMMENTS ABOVE ARE PRELIMINARY DRAFT COMMENTS AS OF 10-28-2010.					

REVIEW 2. INTERNAL REVIEW BY BARR ENGINEERING

Project Number: 34091004.00	
Project Name/Description: Fargo Moorhead Metropolitan Feasibility Study	
Model Name: 500Dec & 2009	
Model Developed By: Houston Engineering	Model Checked By: Barr Engineering
Model Date: 12/22/2010	Model Check Date: 12/29/2010

No.	General Information/Checks	Comments
1	What version of HEC-RAS was used?	4.1
2	What datum is the survey data and the HEC-RAS model in (NGVD29 or NAVD88)?	Not documented in the model
3	Is the datum noted in the "description" box of the main project screen?	No
4	Is the model georefenced and if so what is the horizontal projection?	Yes it is geo-referenced. Projection is not indicated within the model.
5	Is the stationing reference noted in the "description" box of the main project screen?	No
6	Does the stationing in the HEC-RAS model match the map	Not Checked
7	Is the model in the same datum as the mapping? (mapping should be NAVD88)	Not Checked - No Mapping
8	Are photos attached to cross-sections and structures (i.e. photos facing downstream)?	No
9	Are there any modeling or mapping anomalies that should be pointed out to a reviewer?	Yes. There are several locations where cross sections overlap each other. See Overlapping XS tab of this Excel workbook.
10	Are the "Plan" files clearly labeled/named?	Yes.
11	Was GeoRAS used to create your geometry schematic?	Yes
12	Were cross-sections created using both survey data and digital topography (i.e. LiDAR, 2ft topo, etc.)?	Yes. Some cross sections cite survey data by Houston and others cite LiDAR data in the comment boxes.
13	Is the unsteady model computation time appropriate?	Yes, time step is 5 minutes for a 1-month model duration. Inflow hydrographs have data every 12 hours.
14	If there are options checked on the plan file do these make sense?	Yes.
15	If the tolerances have been changed are these appropriate?	Tolerances are 0.03' for XS and 0.1' for storage areas. Presumably tolerances were modified to achieve stability of the unsteady model.

Hydrology Checks		Comments
16	Has the hydrology been reviewed internally?	Not Checked
17	Has the hydrology been reviewed and approved?	Not Checked
18	Is a write-up of the hydrology included?	No
19	Have the reach boundary conditions been reviewed internally?	Not Checked
20	Is the boundary condition a "Known W.S."?	No
21	Do the 10-, 50-, 100-, and 500-yr flows entered in RAS match the flow hydrographs calculated in your model/hydrologic calculations? Are they labeled in HEC-RAS?	Not Checked
22	Are the 10-, 50-, 100-, and 500-yr flow hydrographs labeled as such in the HEC-RAS flow editor?	NA. Due to the size of the model the flow profiles are broken out into separate models.
23	Are there any negative flow hydrographs that may indicate correction hydrographs within HEC-RAS?	Not Checked
24	Do the output hydrographs from HEC-RAS have any abrupt changes?	Wolverton has oscillating flow directions at RS 3017 & 3123, Oakport Upper has significant negative flows just prior to the peak.
25	Are storage areas adjacent to river reach cascading flow ahead of the river?	Not Checked
26	Do the profiles through the entire hydrograph make sense?	Spot check of hydrographs found no glaring problems.
27	Do any river reaches have negative flow?	Yes. See Negative Flows tab of this Excel workbook and comment #9 below.

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Hydraulics Checks		Comments
28	Is a write-up of the hydraulics included?	No - not applicable at this time
29	Do discharge values match hydrologic analysis results?	Not Checked
30	Do the locations where discharges change in the model agree with locations on drainage area map?	Not Checked
31	Do the discharges change along the stream at the appropriate location?	Not Checked
32	Have the "Summary of Errors, Warnings, and Notes" been reviewed and addressed for each profile and floodway?	It was reviewed. Many "Divided Flow", "Conveyance Ratio", "Energy Loss > 1.0 ft" warnings.
33	Has Check-RAS been run, and each issue addressed?	Not Checked
34	For any remaining Check-RAS issues, has the Check-RAS output been annotated?	Not Checked
35	What is the boundary conditions for the starting water surface elevation?	Boundary Conditions vary depending on the reach. There are four types of boundary conditions used. Flow Hydrograph, Uniform Lateral Inflow, Rating Curve, Lateral Inflow Hydrograph
36	Have you reviewed the HEC-RAS profiles?	Many channel bottoms are higher than the inverts of culverts. For example: Drain 37, Drain 37, RS 53721, RS 41967, RS 37537, RS 35831, RS 33145, RS 25187, RS 19050, RS 4853; Possible difference in datums that wasn't adjusted?
37	Do profiles cross for different return periods?	There are several instances of crossing profiles. Sheyenne River - Horace to WF 186215, 186040, 185962, 185750 (500 & 100 yr cross) Drain 34 - 20561.04, 20501.35 (10 & 50 yr cross). See Profiles tab in this Excel workbook.
38	Have you checked the water surface elevations to make sure there is no negative water surface slope?	No negative slopes found for the 500-yr profile or the 2009 event
39	Have you used the 3D viewer (X-Y-Z plot) to review the 100- and 500-yr floodplains and floodway?	Not Checked
40	Are the WSELs on tributaries lower than the WSELs on the main channel at or near the confluence?	Most are ok. Some come in lower. The Sheyenne River - Maple to Red has cross sections that overlap with the Red River conveyance area. The cross sections outside of the red river conveyance area are have a peak profile that is lower than the red river peak.
41	Are there drawdowns on the profiles?	Not Checked
42	What is the source for your Manning's N values?	Not documented in model
43	Has a summary of the range of Manning's N values been created?	Not documented in model
44	Do the Manning's N values seem reasonable?	Yes. However in some locations they are not consistant. Mannings n values (channel and overbank) in Drain 37 are all 0.04. Mannings n values in the Maple River are 0.04 in the channel and 0.08 in the overbanks, with similar terrain.
45	Do the expansion and contraction coefficients seem reasonable?	The default value for contraction and expansion losses is 0.0 for an unsteady flow model (see clip from HEC Users Manual in the C&E Coef tab). However, because this model was developed from previous (assuming) steady state models there are expansion and contraction coefficients entered in the model. Presumably during model development and calibration the contraction and expansion coefficients were reviewed and adjusted as needed. Most seem reasonable for a steady flow model. However there are instances where the upstream and downstream coefficients are 0.1 nd 0.3 for bridges, culverts and in-line structures, which would be low for cross sections located adjacent to a structure. See highlighted rows in C&E Coef tab.
46	Are the cross sections lengths appropriate for the model reach?	some of the reach lengths are still quite long.
47	Are there interpolated cross sections?	Yes.

REVIEW 2. INTERNAL REVIEW BY BARR ENGINEERING

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48	Have Cross-Sections been placed at least every 1000 feet?	No. About 1/3 of the cross sections (1100+) are spaced more than 1000 along the channel. Given the meandering nature of the channel this is reasonable. However, roughly 150 cross sections are spaced more than 5000 feet apart (channel length). Twenty-six of those are over 10,000 feet apart. The vast majority of these are on the Red River near the upstream and downstream ends of the reach. The longest Channel reach length is over 4 miles at 23,310 feet. See Reach Lengths tab - all Channel Reach Lengths greater than 5000 are highlighted.
49	Are the WSELs for every cross section lower than the cross section end points?	No. The flat topography makes this difficult if not impossible to achieve. Most cross sections seem to be extended to a reasonable degree. Storage areas are used to model areas beyond the extent of the cross sections.
50	Are the cross sections perpendicular to flow?	Yes
51	Do the cross sections locations model constrictions and expansions in the floodplain?	Yes
52	Do the cross section locations model structures in floodplains	Yes
53	Do cross sections overlap storage areas?	Yes, some do. Drain 53 Wtsd, Drain 53, RS 9250 through 8779 AND 3975 through 3621; See additional screen grabs in the Overlapping XS tab.
54	Do the locations of bank stations make sense?	Most do. But nearly 300 have bank stations higher than the 500-year WSEL. Reaches include Drain 14, Drain 34, Drain 37, Elm River South Branch, Elm River North Branch, Red River RLR to Drayton, Rose Coul Drain 27, Shey-Div SheyDiv, Sheyenne WF to Maple, Sheyenne Gol to Horace. See highlighted rows in OB Elev tab of this Excel workbook.
55	At road crossings, are there actual road names in the "description" box of your structure data?	In some locations - but not consistantly throughout the model.
56	Are all road crossings being modeled?	Not Checked
57	Are you using the correct "bridge modeling approach" for each bridge?	Not Checked
58	Is the top of bridge roadway being properly defined?	Not Checked
59	Is the correct top-of-road elevation, low-chord elevation, and deck width being modeled?	Not Checked
60	Are the proper coefficients being used for weirs, pressure, and/or culvert flows?	Most Weir coefficients are 1. The following structures have a coefficient of 0.5: Drain 14, Lower, 37000 LS; Drain 14, Lower, 2900 LS; Maple River, Durbin to D14, 16450 LS; The following structures have a coefficient of 2.6 (default): Shey-Div, SheyDiv, 37912.24 IS; Red River, RLR to Drayton, 1549773 IS; Red River, RoseC to OakPt, 2416121 IS, 2384792 IS, 2368258 IS; Maple River, D14 to Mouth, 845 IS; Maple River, D14 to Mouth, 36000 IS; Heartsville, Main, 1311.5 IS;
61	Are levees used, and if so, is a description included?	Levees are used. I haven't seen a description. Most seem to be roads. I think either a levee needs to be put on the left side of Wild Rice ND, BL Aber, RS 169582, or the cross section needs to be extended to include the road on the left side. WSEL goes above the cross section data on the left end.
62	Are ineffective flow areas modeled correctly?	Not Checked
63	Have ineffective flow area been placed at correct stations/elevations?	Not Checked
64	Do the ineffective flow areas contain any drastic changes in width?	Not Checked
65	Are the ineffective flow areas being modeled correctly at bridges that are not overtopped?	Not Checked
66	Is there ineffective flow areas where high ground prevents flow?	Not Checked
67	Is there appropriate control for split flow?	Not Checked
68	Are split flows at lateral overflow weirs set up correctly?	Not Checked
69	Are all lateral flow structures connected to another reach or storage area?	Yes
70	Are all storage areas connected to another storage area or reach via lateral structure or storage area connection?	Yes

REVIEW 2. INTERNAL REVIEW BY BARR ENGINEERING

Project Number: 34091004.00	
Project Name/Description: Fargo Moorhead Metropolitan Feasibility Study	
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Additional Notes:

71	Does the channel width vary from one cross section to the next?	Some cross sections have large changes in channel width between cross sections. See Bank Sta tab in this Excel workbook.
72	Maple River, Durbin to D14, 162161.2BR	Should bridge have a 3rd pier? Simply looks funny.
73	Drain 37, Drain 37, RS 45478	Roadway deck upstream distance and width are 10' and 10'. The two culverts through the road have 35' and 41' as the upstream distance and culvert length. Culverts are not within the road.
74	Drain 37, Drain 37, RS 19050	Distance to upstream XS from deck and culvert are not equal (20' and 1')
75	Red River, RoseC to OakPt, RS 2422105	XS looks like it was inadvertantly moved. Looks like a copy of RS 2424705.
76	WRSA340	Check the initial condition. Resulting hydrogragh starts high with high outflow, approaches "empty", nothing ever comes in.
77	WRSA300	Initial condition seems high. Connection to WRSA305C has 2 box culverts at 904 and 907.4. Initial condition is 913.2. Sends 700 cfs to WRSA305C at time 0.
78	Drain 14, Lower, RS 84.09075	Negative Flow, likely due to passing flood wave at the downstream connection. Some of the "upstream reaches" (Drains, small tributaries) have a negative flow at the downstream end of the reach towards the end of the simulation.
79	Interface of Sheyenne River, Horace to WF and Gol to Horace	Initial condition WS profile seems really funny. Causes a sharp change in the profile at the initial steps. The effects of this are definitely seen downstream to the end of the Sheyenne.

REVIEW 3. INTERNAL REVIEW BY HDR

HDR | ONE COMPANY
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Memo

To:	Stuart Dopperpuhl, Moore Engineering Gregg Theilman, Houston Engineering Lee Beauvais, Moore Engineering Miguel Wong, Barr Engineering		
From:	Mark Forest, HDR	Project:	FARGO-MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT
CC:	Michael Johnston, HDR Nate Dalagar, HDR		
Date:	February 25, 2011	Job No:	145025

RE: Technical Review – Unsteady Flood Models

Purpose

The purpose of this memo is to present the findings from a review of the 2009 calibration unsteady flow model (2009.prj), the synthetic event models and the LPP alternative models as one set of combined comments. Previous comments had been provided by HDR on November 3, 2010 and January 21, 2011. These previous comments have undergone some revisions and additions in this set of comments. This memorandum supersedes those previous two memorandums.

Comment Response and Comment Closure

Since this memorandum supersedes those previous two memorandums, comment closure on the previous two sets of comments may not be needed. Comment responses to this set of comments would be more appropriate since this set of comments has been revised to reflect additional review based on additional information and updated models. Closure of these comments is recommended for project QA/QC documentation purposes.

Data Provided For Review

Data provided included:

Additional data was transmitted by FTP site that included inundation mapping for the 2009 event. A revised version of the 10-, 50-, 100- and 500-year event existing conditions models dated February 18, 2011 (ExCond.prj) was also provided to replace the December 2010 and January 2011 versions of these models.

The models included in this final review include:

<u>Historic Events – Existing Conditions (Calibration and Verification)</u>
- 1997 (1/28/11)
- 2006 (1/27/11)
- 2009 (1/27/11)
- 2010 (1/28/11)

<u>Historic Events - LPP:</u>
- 1997 (Version 5, 2/18/11)
- 2006 (Version 2, 2/16/11)
- 2009 (Version 4, 2/18/11)
- 2010 (Version 4, 2/18/11)

REVIEW 3. INTERNAL REVIEW BY HDR

Synthetic Events – LPP:
- 10-Year (Version 6a, 2/18/11)
- 50-Year (Version 7, 2/16/11)
- 100-Year (Version 14, 2/17/11)
- 500-Year (Version 13, 2/16/11)

Additional Data Provided as Background or Supporting Information:
- Phase 3 Report
- LPP_minus_ExCon_100YR_Feb17_North_detailed_scale.pdf
- LPP_minus_ExCon_100YR_Feb17_South_detailed_scale.pdf
- LPP_minus_ExCon_500YR_Feb16_North_detailed_scale.pdf
- LPP_minus_ExCon_500YR_Feb16_South_detailed_scale.pdf
- ExistingConditions_DepthGrids.pdf
- FCP_Downstream_Book.pdf
- LPP_Downstream_Book.pdf
- LPP_Upstream_Book.pdf
- MN_DepthGrids.pdf
- ND_DepthGrids.pdf

This review focused on model structure, stability and data fit to observed data. The hydrologic data used to represent the calibration and synthetic events were not reviewed. It is my understanding that QA/QC review of these project elements was performed by others. The review was initiated with the 2009 event calibration since it provides the basis for most of the model parameters used in simulation of the synthetic events. Comments pertaining to the synthetic events follows the comments pertaining to the 2009 calibration.

Model Suitability for Feasibility Analysis

The stated purpose of this modeling effort was for a feasibility level study. At the feasibility level, it is anticipated that future refinements may be necessary to refine the selected alternative(s) and ultimately to accurately reflect the selected design condition and for quantification of project benefits. The comments represented in this memo are not atypical of the types of refinements needed as the project progresses into the next phases of concept refinement and design. In general the model appears to provide a very reasonable simulation of the observed events in recent years. The model also reasonably simulates the complex behaviors that are observed in the field measurements made by the USGS at a number of locations throughout the project area. Therefore, while the comments demonstrate the need for some model refinements during the ongoing planning and design process, these comments do not suggest that the model is not adequate for feasibility level planning evaluations.

It is my observation that refinements to the hydraulic models would provide some improvements to the model results, particularly on the tributaries to the Red River. The level of refinement needed will vary depending on the needs for identification of project impacts and quantification of project benefits. In other words, some of these tributaries may not need to be refined if those reaches are used primarily for routing of hydrographs within the study area but the results are not used for evaluation of impacts, benefits or interior drainage.

The greatest level of uncertainty in the model is the hydrology. The limited gage data on many of the tributaries creates a higher degree of uncertainty with respect to hydrograph shape, volume and timing of tributary hydrographs entering the Red River from the tributaries. There may also be uncertainty with regard to the variability between events that has occurred historically from these tributaries. The uncertainty in the hydrology is particularly important in this case due to the very shallow gradients of the watercourses in the study area. These very shallow gradients result in more pronounced backwater impacts from flow and volume variability that extends for significant distances upstream of a confluence. This condition is noted in the data presented below that shows that at many gage locations the stage can vary by 2 to 8 feet for a given discharge because of these downstream influences. These differences can be event variability or differences noted between the observed stages during the rising and receding limbs of an event hydrograph.

In addition, modeling tools are undergoing very rapid improvements in their capability to simulate the complex channel and overbank behaviors that are exhibited in this study area. For example, future phases of this project will be able to take advantage of the two dimensional tools that are in the process of being incorporated into HEC-RAS by the team at the Hydrologic Engineering Center. These enhancements to HEC-RAS should allow more accurate simulations of the project features that are currently proposed in this feasibility study. This project may also present a unique opportunity to test those new HEC-RAS two dimensional modeling features during the beta testing phase of the software.

Comments – General Comments

1. This model is extremely complex and includes data from other modeling efforts on many of the tributaries. It is recommended that the source of data for each model element be clearly documented relative to the source of the data, level of detail it represents, verification of model inputs as well as any known limitations with the data sets. For example, the data set for the Elm River does not include some of the bridges. Therefore, the water surface profiles for the Elm River would not be accurately represented and should not be used for any purpose. If these were used to simply route inflow hydrographs from gage or model hydrograph input locations, this should be documented in the hydraulic report with a warning regarding the use of the resulting water surface elevations and flood limits. It was also be important to verify that these inaccuracies would not impact the flood damage and benefit calculations.

2. Due to the shallow gradient combined with the large tributary volume that joins the Red River in the study reach, the system exhibits significant backwater influences that vary from event to event depending upon the timing and volume of tributary inflows. As will be exhibited from the data presented below, the system can have a wide range in stages for the same discharge.

3. Since not all of the tributaries are gauged, development of statistics for coincident flows is not possible for each watercourse. Therefore, simplifying assumptions are required and have been applied to both the calibration models and synthetic events. These conditions demonstrate that one of the greatest uncertainties in this modeling effort is the hydrologic inputs. Determination of downstream impacts may need to consider this uncertainty with a sensitivity analysis during later stages of design refinements.

4. During the evaluation of these models, HEC-RAS version 4.1 was found to have a bug that prevented complete post-processing of the output data. This was resolved by HEC with the provision of a beta version of 4.2 that could be used to post-process the computations performed by version 4.1.

5. HEC is in the process of developing 2D modeling options for use within HEC-RAS that will integrate with the 1D channel elements. While they have made significant process on the development of the 2D model code, HEC has reported that the beta version that integrates this code into HEC-RAS will not be available until the first half of 2012. The timing of this release could coincide with future refinements of the models for this project as the design progresses and could provide a very useful tool for modeling the complex overbank interactions that occur in the study area.

6. Many of the bridges in the model have piers and profiles that are overtopped during higher flow rates. The methods selected typically include only the energy method for both low flow and overtopping conditions. Consideration of momentum for low flow and pressure/weir flow for overtopping conditions should be considered. It is recognized that multiple recurrence intervals being analyzed with the same data set. In cases where there is submergence of the bridge (such as in the 500-year profile), the energy equation would be more appropriate. While that same bridge may have weir flow in the 100-year event without complete or highly submerged conditions. In that instance, the bridges modeling methods may vary between recurrence intervals to reflect these ranges in conditions

7. A key consideration in setting up a one dimensional model is appropriate alignment of each cross section to maintain a cross section that is consistently perpendicular to the flow patterns in the floodplain. This is important for two primary reasons; incorrect alignment can bias flows especially with wide overbank flow, and incorrect alignment misrepresents where the water surface elevations are represented in the floodplain for determining extents and depth or misrepresent the water surface at a lateral structure that is located at the end of the cross section. This often requires more than two angle points in the cross section alignment to accomplish this. Typically (as described in the RAS manual) this requires starting with a map that shows the primary flow vectors in all parts of the floodplain. Sometimes this is a reasonable approximation based on the topographic mapping that might have to

be re-evaluated after a preliminary model is established. Flooding event photos and video often provide valuable insights. Due to the very shallow gradients that are experienced in this project areas, this may not be a significant factor, but should be reviewed for reasonableness.

8. Choice of bank stations is important and should be consistent. Typically the bank stations are either at the edge of the active channel (near ordinary high water) or at the break in slope at the top of bank. These decisions should carefully consider how conveyance is being represented as well as velocity distributions in the channel. If the model will be used for computing scour or doing a floodway analysis, choice of bank stations is also a critical consideration. The plot below (Figure 1) shows variability in bank station elevation that appears to suggest some inconsistency in the selection of bank station location.

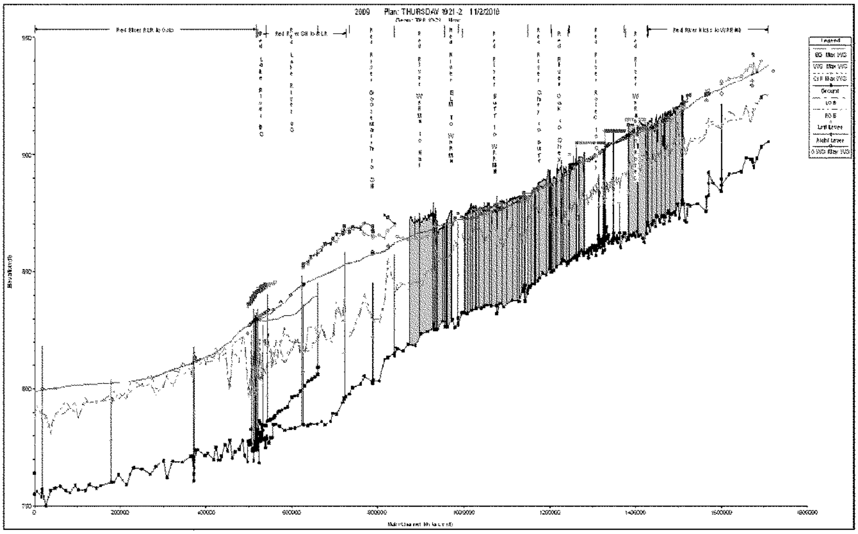

Figure 1 - Plot showing inconsistent bank stations

9. The maximum iterations is set to 20 rather than the maximum value of 40. At some cross sections, the model reaches the maximum number of iterations. Minor improvements could be obtained by changing this value to 40 to allow those locations to come closer to closure on the solution.

10. Cross section 2422105 appears to have an error in the georeferencing (see Figure 2). The n values for the main channel on the Red River are set to 0.045. Photos suggest that the main channel roughness should not be that high, as seen in the photo below (Figure 5). However, the velocities in the main channel range from 1.3 to 3.5 feet per second for the Red River in most parts of the model. So, the model is likely to be relatively insensitive to this parameter. More frequent events may be more impacted by a high estimate of n value than the extreme events.

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Figure 2 - Example Photo of Main Channel

11. Some of the cross sections overlap one another in the overbank areas (see Figure 3 and 4). This condition should never exist for a number of reasons. From a hydraulic perspective, cross sections should not overlap or cross once another. This suggests that two computed water surface elevations occupy the same space and conveyance may be using the same area. From a post-processing perspective, the output will also represent two different elevations at the same location (overlapping breaklines).

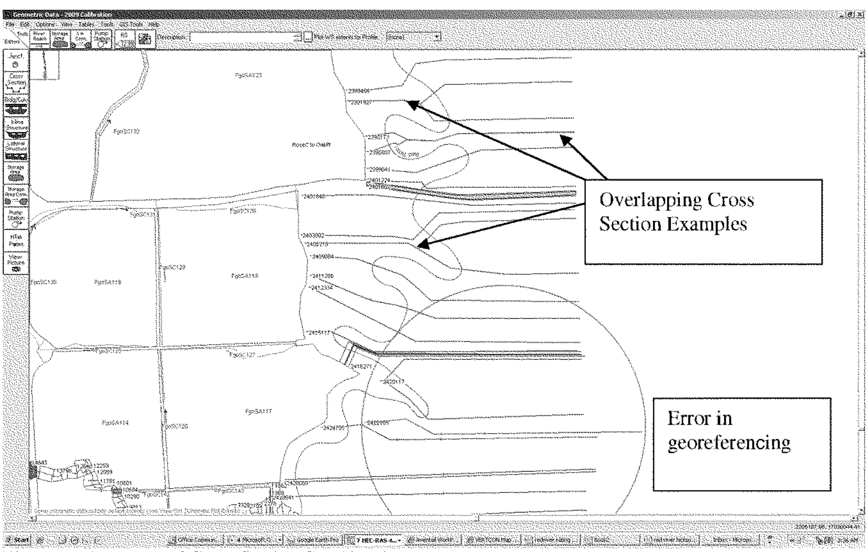

Figure 3 - Examples of Cross Section Cut Line Problems

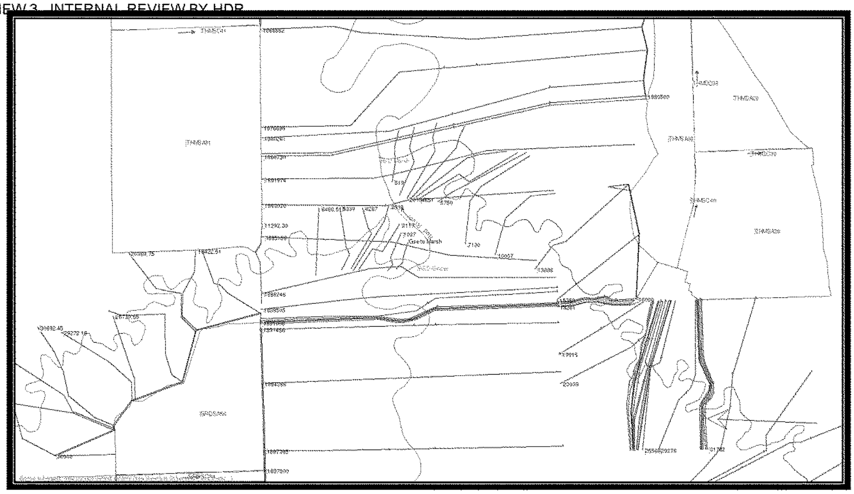

Figure 4 - Overlapping Cross Sections

12. Weir flow coefficients for storage area connections and lateral structures can range from values less than 1 for flow overtopping a natural ground topographic divide to values in the range of what was used (2.6 for storage area connections and 2.0 for lateral structures). I spoke to Gary Brunner (HEC) again about this topic in November. He and I also explored a range of values for use in a similar unsteady flow model for the Truckee River Project in Nevada. HEC-RAS uses the defined values for a starting point and then checks tailwater and headwater at each time step to check for submergence. The values are adjusted for submerged conditions and it will also calculate flow in both directions depending upon tailwater and headwater conditions for that time step. Often use of values above 2 can generate flows across lateral structures that are too rapid. A number of factors should be considered when selecting these values:

    - Is the overtopping section is a paved section with little or no vegetation?
    - What does the overtopping feature look like with regard to roughness, width, irregularity, etc?
    - Is there shallow sheet flow that occurs between the overtopping section and the next downstream section or ponding area (if it is connected to another storage area). RAS does not explicitly consider the overland flow component. The calculations assume a series of cascading reservoirs when storage areas are linked in series. The flow from the storage area outflow reports directly to the connecting element. Therefore, your only means for slowing down this flow connection, is to use a lower weir flow coefficient (when using a broad crested weir).
    - If the high point is natural ground with an uneven surface and vegetative coverage, this value could be less than 1. There is no specific guidance for the selection of these values. Calibration or validation runs using observed data is the only way to verify these decisions. We had very good validation data for the Truckee River model. It required values that ranged from 1.0 to 1.5 in many instances that are similar to this example, in order to get reasonable results.

Comments – Calibration Events (Existing Condition)

13. The "observed" hydrographs within the model domain are based on a best fit rating curve using direct and indirect measurements at this location. The model shows that the rating curves at many of the gage locations are looped, which suggest that the observed hydrograph at these location could be suspect. The USGS typically converts the recorded stage hydrograph into a flow hydrograph using a rating curve that is based on the best fit to the field measurements. The looped rating curves noted at many locations within the data set suggest that a single rating curve would provide an imprecise

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method for estimation of the flow hydrograph from the recorded stage hydrograph data. If the rating curve during the rising limb differs from the rating curve during the receding limb, a single rating curve could be inaccurate. As a result, the hydrograph shape and volume could be misrepresented. The observed hydrographs may need to be adjusted based on an improved rating curve considering this behavior during the rising and receding limb of the hydrograph. This may significantly change the hydrograph volume for the observed hydrograph which will change your inflow hydrographs as well. Adjustment to the observed hydrographs and input hydrographs to account for the different rating curve that exists during the rising and falling limb of the hydrograph, could improve the volume inputs to the model and the results comparison to observed data. I would recommend that this be discussed with the USGS to determine if this behavior has been documented or considered, and the results of that discussion be documented in the report. I would also suggest that the potential range of error be tested using one of the observed hydrographs to see if the volume estimate changes significantly.

14. Do we have flood photos or videos that would be helpful to confirm flooding extends and flow behaviors? If so, how well does the model match those observations? If this information exists, it would be useful to show comparisons on the reports of model results compared to observed behaviors (inundation limits, overtopping of lateral structures and storage area connections, depth at buildings, etc.. This is useful validation information.

15. In some reaches we are matching high water and in some we are high or low. It is assumed that some of the high water data are from gaged locations which can usually be considered to be reliable. If some of the data is not from gage locations, how confident are we in quality of those data? Did we verify that these data were collected in areas that were reasonably protected from wave action or local turbulence? With regard to areas where we are low upstream of bridges, version 4.1 does allow you to use higher contraction and expansion losses where more severe contractions and expansions occur. The unsteady equations account for most of these pressure terms without needing to include additional contraction and expansion losses. But, there are times when additional losses do need to be considered with contractions or expansions that are more severe. These values are used differently in the unsteady solution than how they are used in the steady flow solution. Typically the values you would use are slightly lower than the values you would choose for steady flow. In areas where we are too high, we may need to consider our potential sources of error.

16. The match to the observed hydrograph near the downstream end of the model, appears to be a reasonable match for the 2009 calibration event for peak flow and timing but appears to have insufficient volume. The observed hydrograph could be somewhat misrepresented if the USGS uses a single rating curve to convert the recorded stage hydrograph to a discharge hydrograph due to the looped nature of the rating data that can be seen in Figure 6. The volume during the receding limb appears to be underestimated. The USGS data at this location suggest some looping behavior in the rating curve that is more pronounced for flows less than 40,000 cfs (Figure 6). This behavior is controlled or muted in the model by the fixed rating curve that is used as the downstream boundary condition. The model would need to be extended downstream to capture that behavior in the unsteady flow model at this location.

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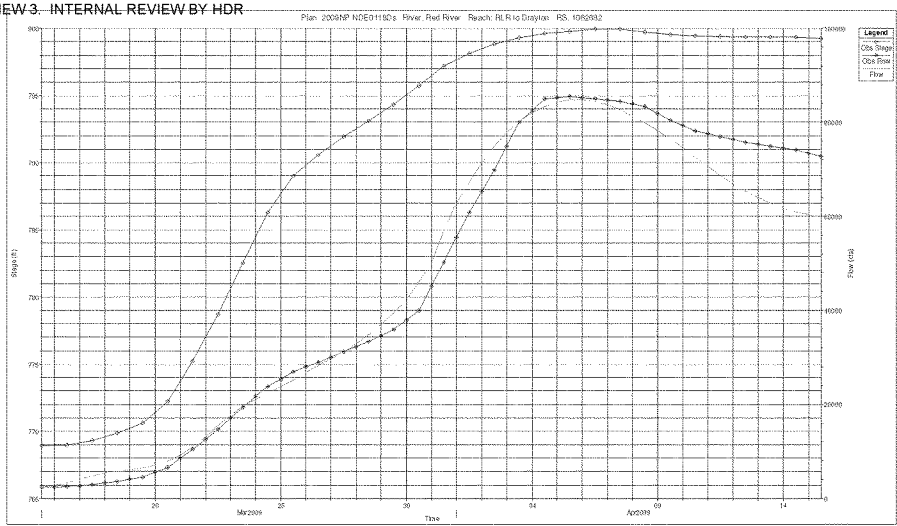

Figure 5 - Red River at Drayton Comparison of Computed and Observed Hydrographs at USGS Gage 05092000, Cross Section 1062682

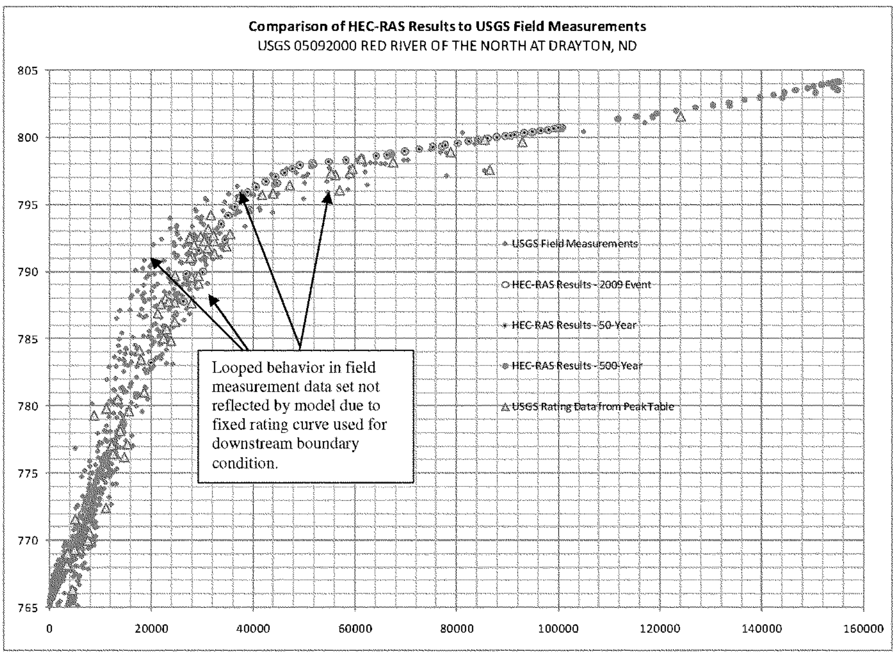

Figure 6 - Comparison of USGS Field Measurements to Model Results, Red River at Drayton, CS 1062682

17. Figure 7 compares the model results to the USGS field measurements at the Grand Forks Gage. The data suggests a fairly reasonable match at higher flow rates but more conservative estimates of stage for flows between 10,000 and 60,000 cfs. There is also a minor looping effect observed in the field measurements that is not represented in the model results.

18. The match to the rating curve and hydrograph at 2388223 is a reasonable match to observed data and shows a very slight over-prediction of stage during the rising limb and a slight under-prediction of stage and flow during the receding limb compared to the USGS data (Red River of the North at Fargo, ND). However, as discussed in Comment #14, the direct measurement data suggests a looped rating curve that is more pronounced than the model suggests (see Figures 9 and 10 below). Figure 10 superimposes the 2009, 50-year and 100-year model HEC-RAS results on the USGS measurement data and the published peak and stage values from the peak flow data table. The USGS data is on the 1929 datum. An approximate correction of 1.0 feet was used to adjust the data sets to match. While the data set appears to be reasonable match at the upper end, the model suggests only a limited loop for the 2009 event, but a more pronounced loop for the 50-year and 100-year events. The measurement data shows a wider variability in stages for a given discharge at the lower end of the curve. I would suggest that we verify the rating data used by the USGS for conversion of the stage hydrograph to a flow hydrograph. If they are using a different rating curve for the rising and falling limbs, these ratings should be compared to the model output data to determine differences between observation and model results. Since the degree of variability can be influenced by the volume, magnitude and duration of the observed event, it may not be possible to make any strong conclusions from these data without further evaluation of other historic events

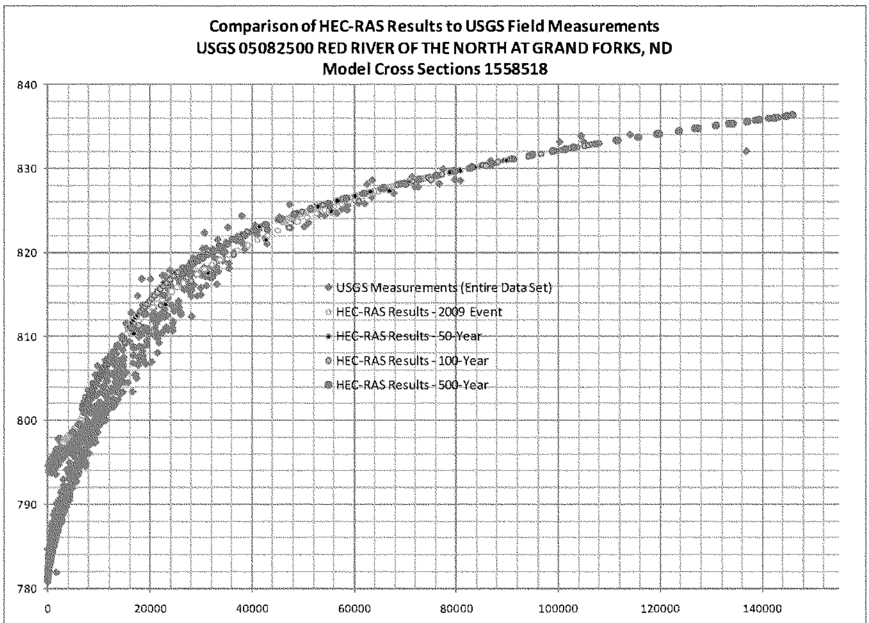

Figure 7 - Comparisong of Model Results to Field Measurements at Cross Sections 1558518

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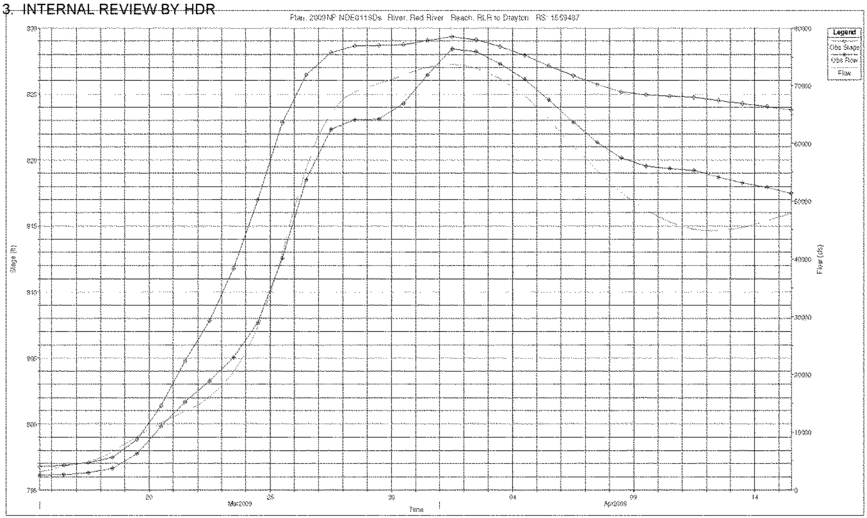

Figure 8 – Comparison 2009 Event Observed and Computed Hydrographs at Cross Section 1558518

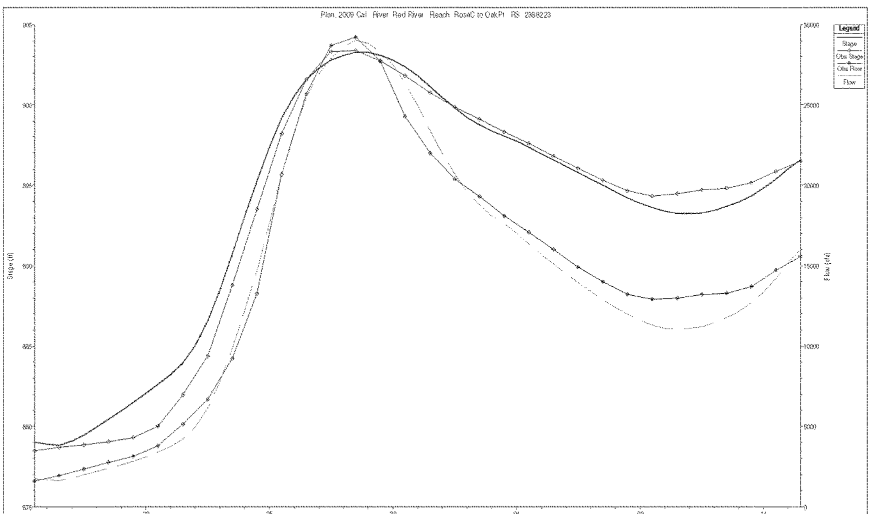

Figure 9 – 2009 Event Calibration Results at Red River Section 2388223

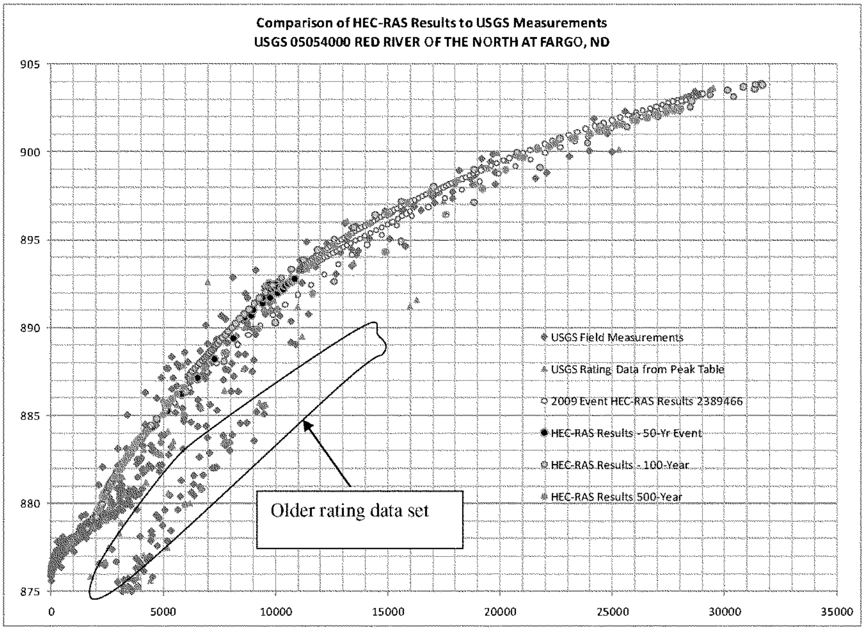

Figure 10 - Comparison of RAS Results (Yellow Dots) at 2388223 to USGS Field Measurements (Blue)

19. A comparison of the USGS field measurements was made at cross section 2563754 (Figure 11). The results appear to be a relatively reasonable match and suggest a pronounced looped rating curve as does the field measured data set. However, the model results show a much more pronounced looped effect than the USGS rating data seems to suggest. The data also suggests that magnitude of the looped behavior varies significantly between events. This would suggest that the rating data used for conversion of the stage to flow hydrographs may not be a good fit to every event. As can be seen from the published peak flow data set, that the published estimates for the recorded peak stages are based upon an assumption that there is a lesser looped effect. I would suggest that we obtain the rating data from the USGS and compare it to the model results.

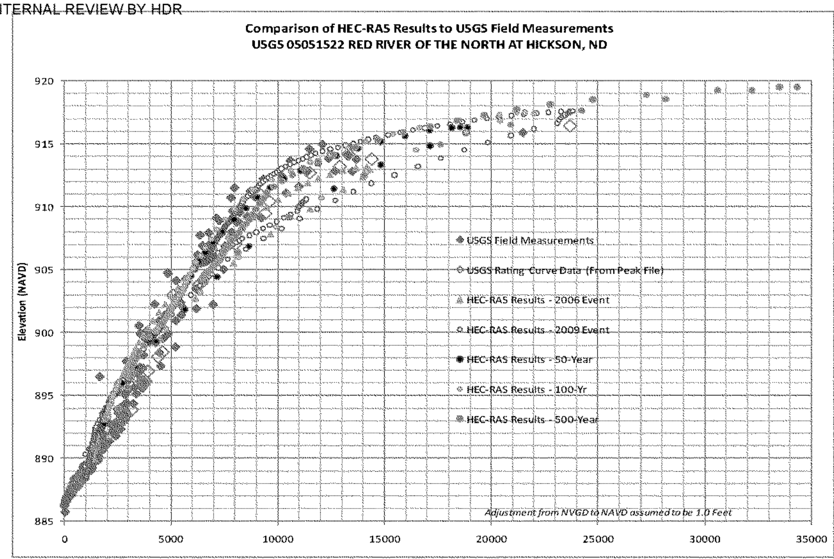

Figure 11 - Comparison of Measured and Computed Stage Data at Cross Section 2563754

20. The match to the observed hydrograph at cross section 10470 of the Buffalo River is not a good match (Figure 12) for a location that is near the upstream end of the model. This suggests that the inflow hydrograph should be adjusted or additional inflow is occurring that is not accounted for. The volume at this location does not match the observed hydrograph.

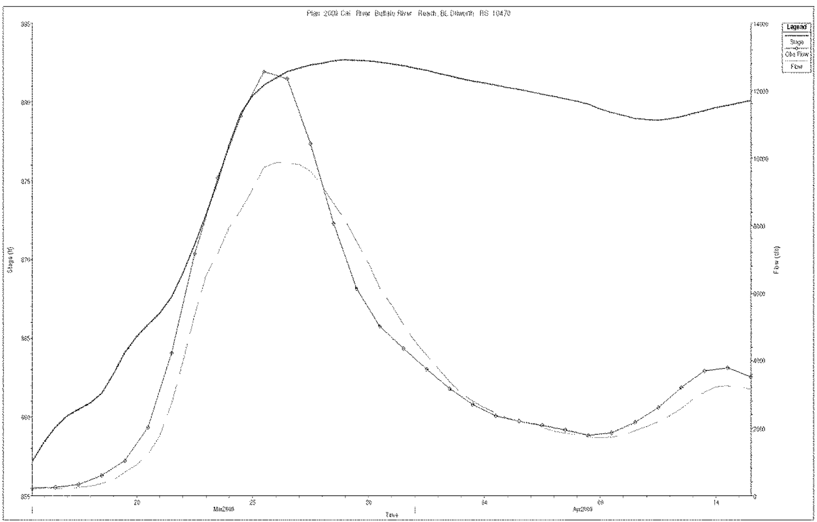

Figure 12 - Hydrograph Comparison at Buffalo River at Station 10470

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21. There is a gage at the downstream end of the Buffalo River Reach (USGS 05062095 BUFFALO RIVER AT U.S. HWY. 75 IN GEORGETOWN, MN). The USGS site says that the state maintains the data base. Did you verify if data was available? A gage at this location would provide useful calibration data.

22. The behavior of the Sheyenne River at 12th Avenue is very erratic due to downstream backwater influences (Figure 13). The comparison of the model results with the USGS field measurements shown in Figure 13 seems to suggest that the predicted stages are generally underestimated by as much as two feet. The datum associated with the USGS gage may need to be verified to determine if this is a model inaccuracy or datum shift. In this case, the datum is reported to the nearest hundredth of a foot which suggests that it has been surveyed.

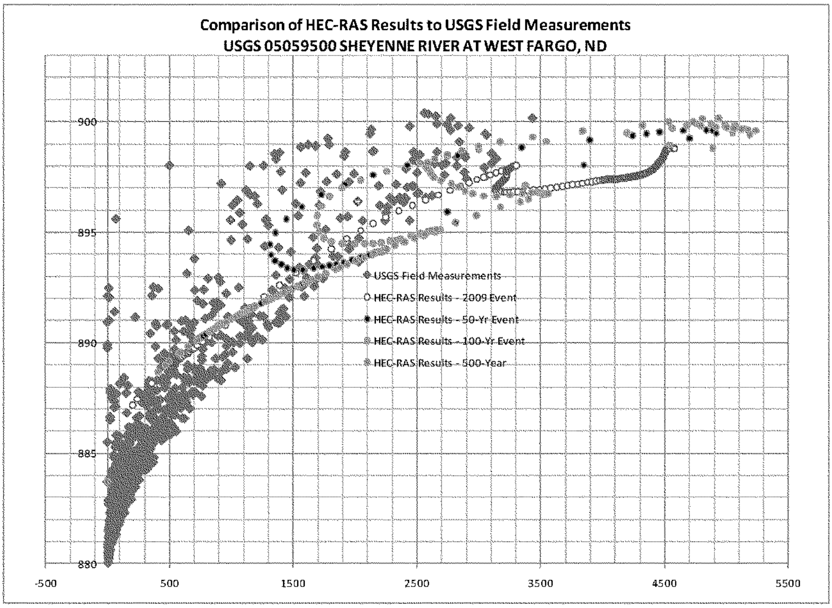

Figure 13 - Comparison of Measured Values and Results at 12th Avenue

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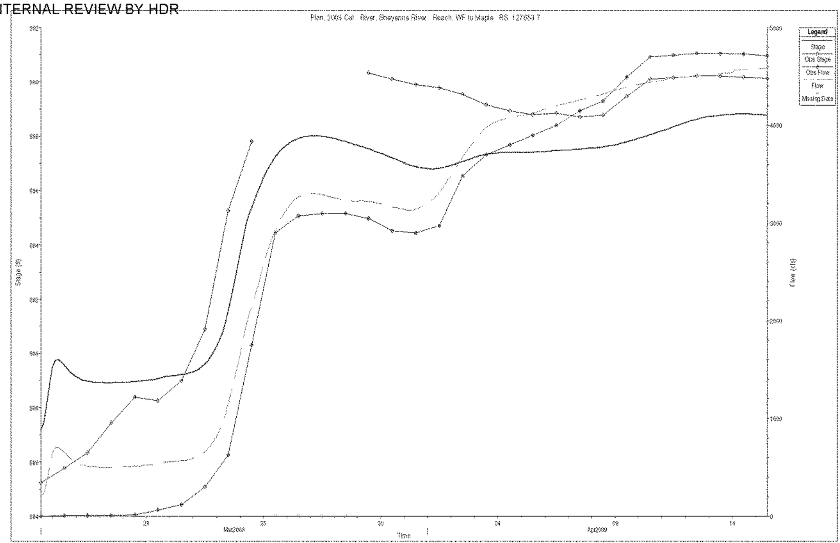

Figure 14 - Comparison of Observed and Computed Hydrographs at 12th Avenue

23. The Sheyenne River downstream of the above reach (Figure 15) should be inspected for potential causes for the underpredicted stages at this location. One potential cause is the fact that there is a bypass channel downstream of this location that is being modeled as a single cross section, rather than as two interconnected reaches of the same stream. This approach also requires that the bridges downstream being modeled as a multiple opening analysis with the same water surface elevation at each opening. The bypass channel also has a shorter reach length and is at a different elevation profile compared to the natural channel. If it is important to accurately predict water surface elevations in this area, better results could be obtained by modeling these reaches separately.

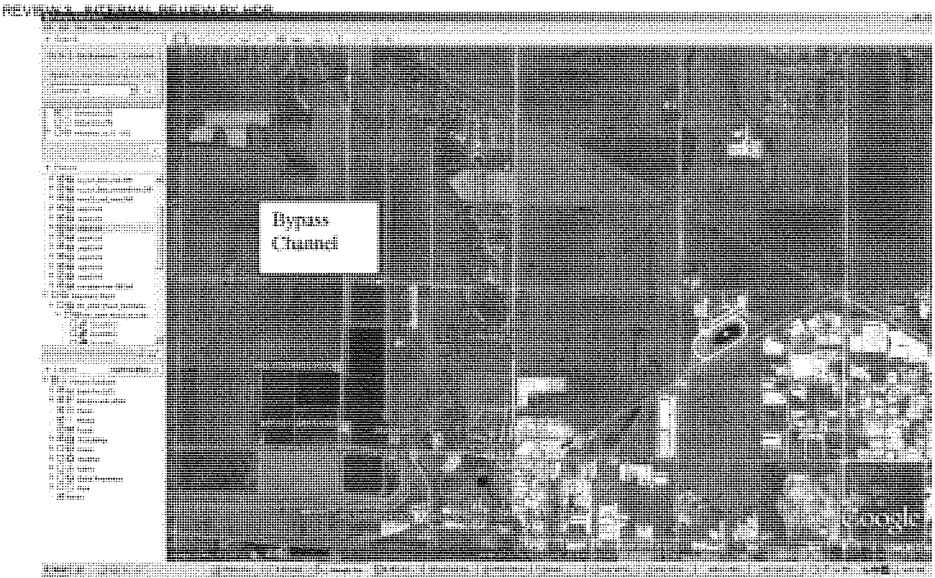

Figure 15 - Sheyenne Reach Below 12th Avenue

24. The Sheyenne River at Cross Section 71250 was compared to USGS field measurements (Figure 16). Comparison at this location may be difficult since it appears that that gage datum is approximate. However, two things are noted in the comparison. First, the range of stages due to downstream influences varies between the more frequent and less frequent events. Secondly, it appears that the model is over-predicting stage for the lower flow rates compared to observed events. The match is better as higher stages.

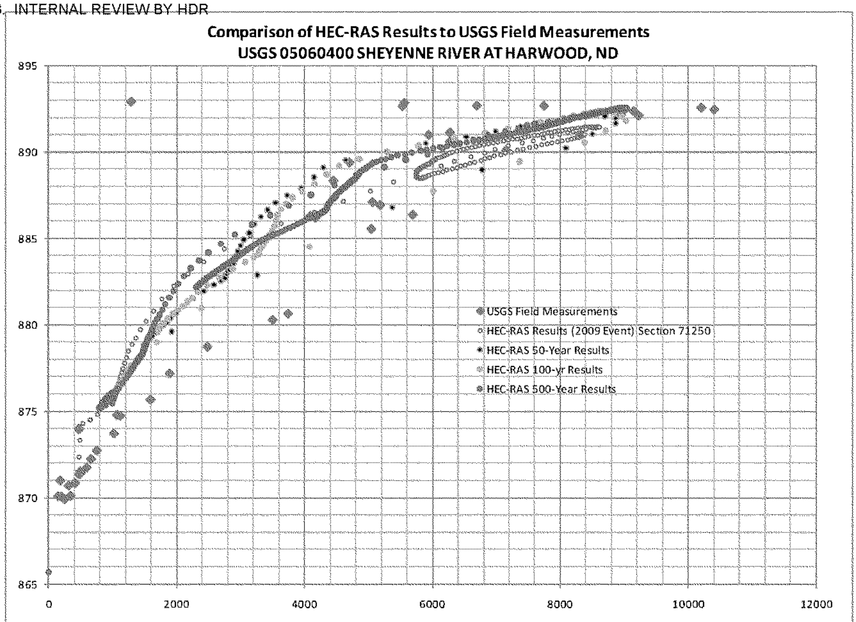

Figure 16 - Comparison of USGS Field Measurements to Results at Cross Section 71250

25. The inflow hydrograph for Drain 14 is entered as a lateral inflow hydrograph over a large reach of Drain 14. The aerial photo (Figure 17) suggest that this inflow enters as at a concentrated location:

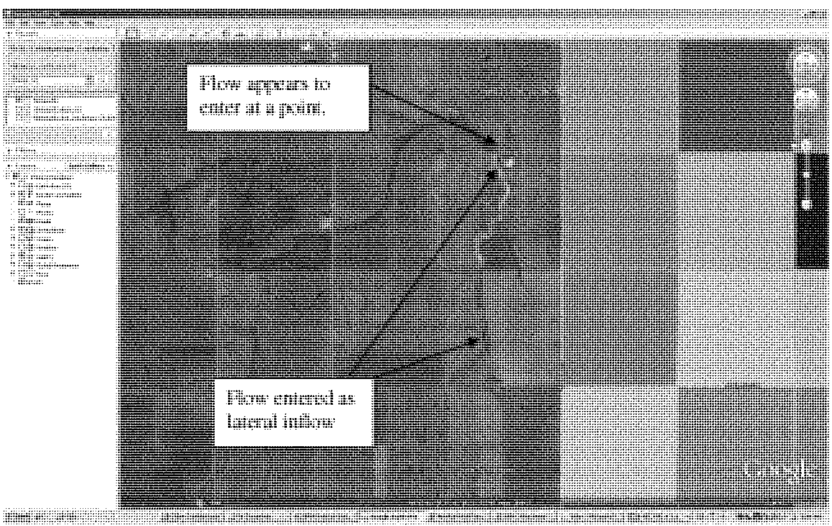

Figure 17- Drain 14 Inflow Hydrograph Comment

26. The sources for the inflow hydrographs for ungaged locations should be explained in the report.

27. When executing the model, a warning message is generated at Goose Creek cross section 6488. The hydraulic properties table includes data to elevation 860.8, but the maximum water surface reached 860.1, resulting in this message. This is caused by user specified HTAB parameters. At this cross section, an interval of 0.33 feet is specified which causes the values to only be computed to an elevation of 860.8.

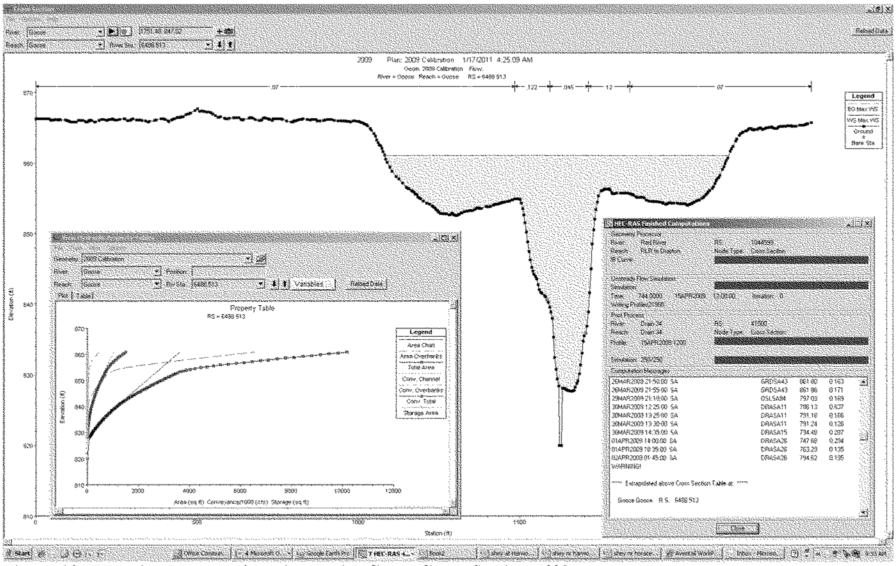

Figure 18 - Warning Message Associated with Goose Creek Section 6488

28. Lateral weir 135900 on Wild Rice is not properly linked and is showing up as overlapping the downstream lateral weir.

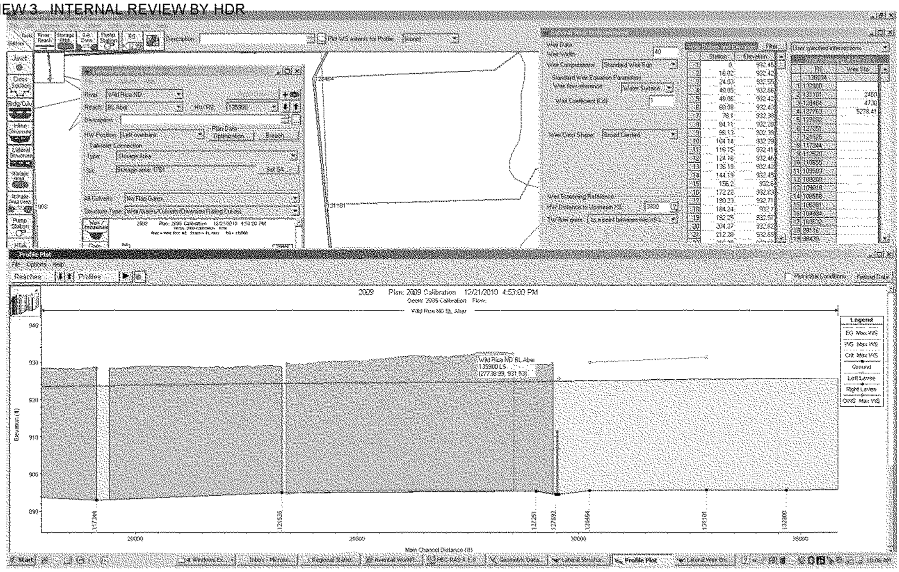

Figure 19 - Wild Rice LS 135900

29. The top of roadway deck for the bridge at cross section 1558704 (Red River) does not appear to be complete on the right side.

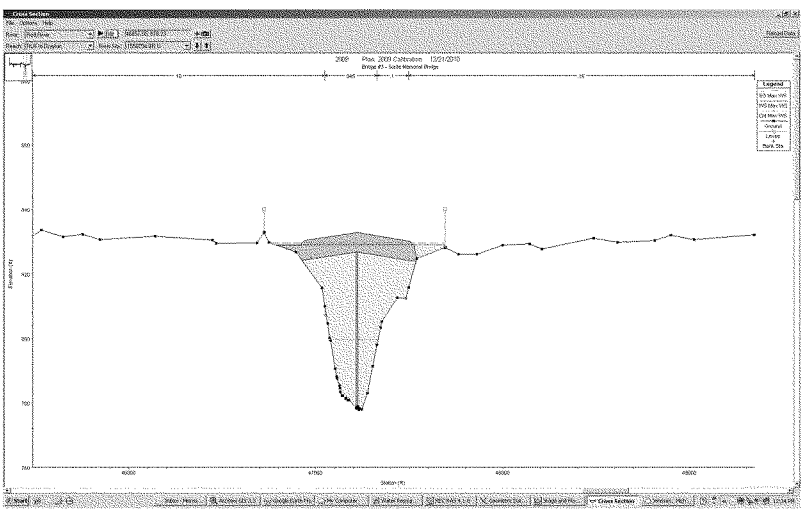

Figure 20 - Red River Bridge #3

30. The culverts on Drain 34 (i.e., 25749, Figure 18) are shown as being perched above the channel bottom. Is that correct?

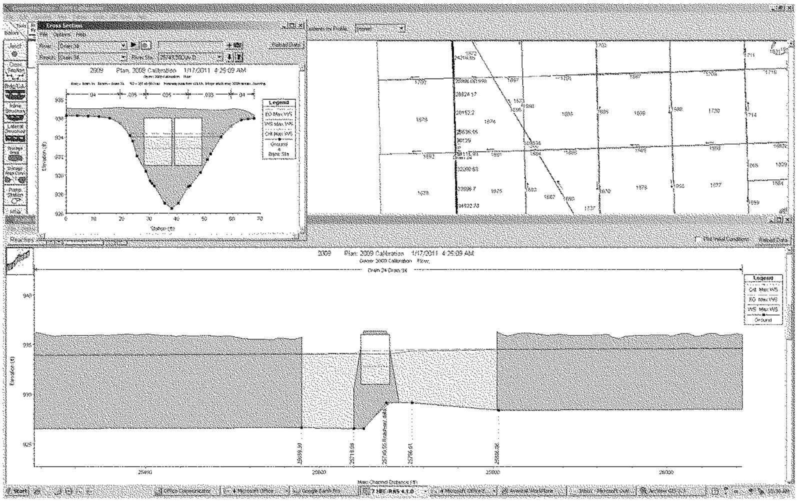

Figure 21 - Drain 34 Perched Culvert

31. There are two bridges in the upstream reach of the South Branch of Elm River that are not included in the model. If the bridge is not going to be modeled, I would suggest the deletion of the cross sections on the upstream side of the first bridge.

32. Many of the bridges are missing from the North Branch of Elm River also. The cross section orientation and inclusion/exclusion of flow in portions of the cross section appear to be inconsistent with flow dynamics.

33. Warning messages suggest that there are several locations within the model where the conveyance ratio or energy losses in excess of one foot suggests that additional cross sections may be needed. Adding additional cross sections at some of these locations could improve model stability.

34. The 2009 event had a peak discharge and volume that is substantially less than the 100-year and 500-year volume. There is a lack of sufficient data to perform a validation or calibration for events in this range of magnitude.

35. The culverts at Drain 37, 37537 are shown to be below grade (Figure 20) which suggest that they should either be partially filled with sediment or the channel data is not capturing the actual invert. This condition exists on some of the other culverts in this reach, suggesting that the channel invert data might not be accurately represented.

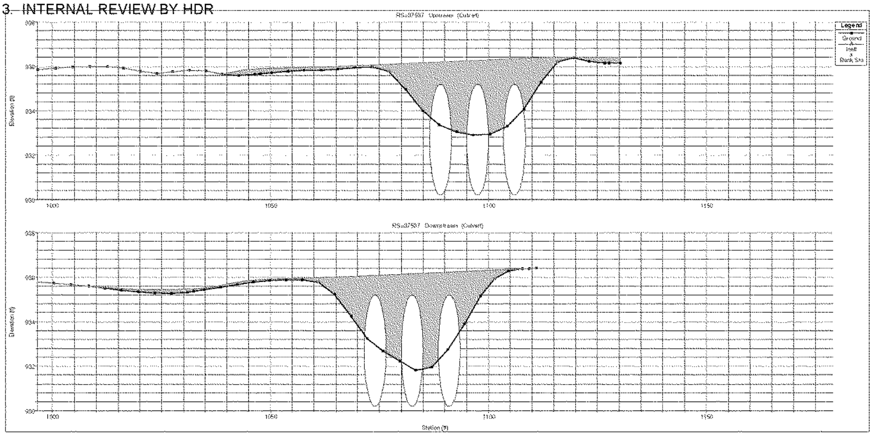

Figure 22 - Drain 37, Culverts at 37537

36. A comparison between the post-processed inundation limits should be made to event photos to validate the flooding extents predicted by the model. This information was not available for my review.

Comments – Synthetic Event Existing Condition

37. The comments above that pertain to the 2009 model are also relevant to the synthetic event models.

38. The hydrologic inputs to the synthetic event models were not reviewed. I understand that an independent review of those data has been performed by others.

39. At some locations, the balanced hydrographs have been entered for comparison. However, in many locations the balanced hydrographs are missing which does not allow a direct comparison between the target discharge and hydrograph volume.

40. A comparison needs to be made between the model results and the peak discharge estimates by the Corps. A quick comparison of the 100-year model results show some discrepancies between the two sources. The hydrology report prepared by the Corps provides a 100-year peak flow estimate of 112,000 cfs at Grand Forks and 67000 at Halstad. The model shows a peak flow of 108,000 and 71,400 cfs at these locations, respectively. How will these variations be reconciled?

41. It is not clear why the flows are being constrained by artificial levees in the Grand Forks Reach (Figure 23 and 24). The aerial photos do not reveal any levees at the existing channel banks. This may be the cause for the higher predicted stages that can be observed in Figure 7.

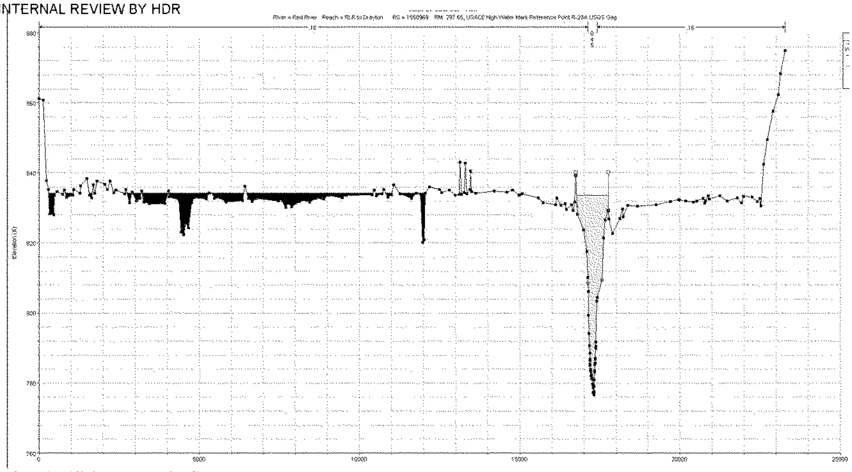

Figure 23 - Artificial Levees in Grand Forks

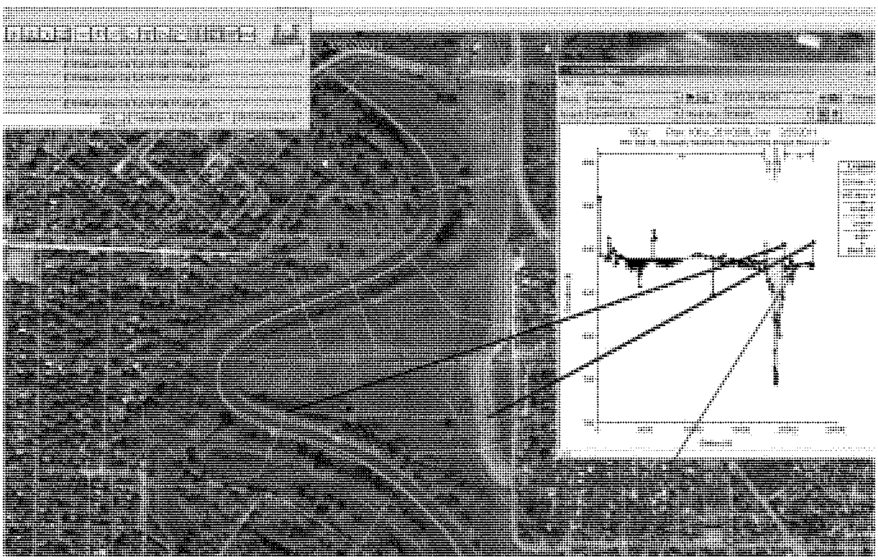

Figure 24 - Grand Forks Reach - Question Pertaining to Artificial Levees

Comments – Proposed Condition for LPP

42. Many of the comments above pertain to the proposed condition model also.

43. The 100-year model goes unstable near the very end of the simulation.

44. I am assuming that independent verification has been performed of the data inputs to assure that the data represented in the model geometry matches the preliminary plans. I did not perform these checks.

45. The design concept requires human intervention based on operational criteria for downstream flows and predicted inflows. Have alternatives been explored that do not require gates? Assuming that other outlet configurations have been explored and found to be deficient, how much risk is associated with the range of potential system flow contributions and variability in how the operating criteria might be employed?

46. Area 1 has a bottom elevation that is 25 to 30 feet higher than the diversion channel. Would additional storage benefit be obtained from lowering the bottom of this storage area to gain additional storage volume?

47. Minor differences in flow volume are noted between the existing and proposed condition in the downstream reaches that appear to be due to changes in residual storage that occurs in many of the storage areas. Elimination of overflow into these areas as a result of project improvements would result in reductions to these residual volumes that remain in these storage areas after passage of the peak flow. This would be an anticipated result. How much potential residual storage occurs after an event may be difficult to quantify without more drainage structure data.

48. The flow conditions at the diversion structures (Figure 25) are complex and vary with stage. This area would likely benefit from the future two dimensional capabilities of HEC-RAS.

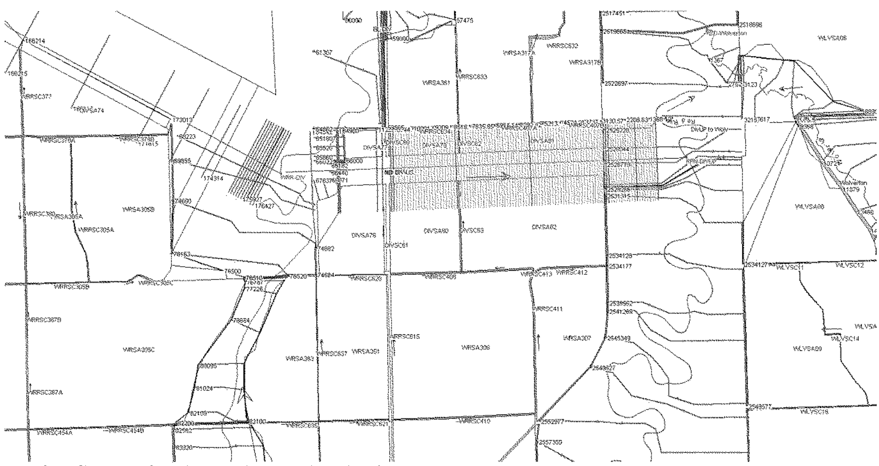

Figure 25 - Complex flow interactions at diversion features

49. A very large flow value is reported for several of the storage area connections such as DRASC33 (see Figure 26) and many of the OSLSC connections (Figure 27) that should be checked.

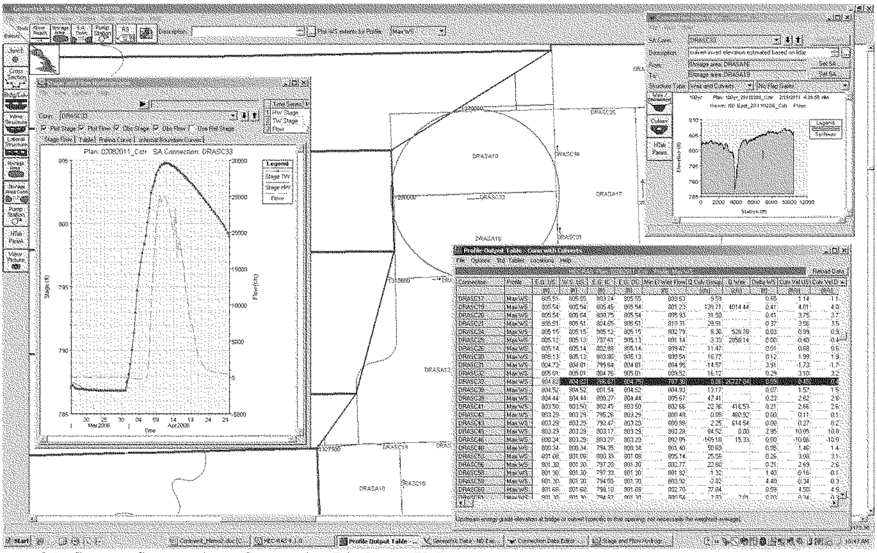

Figure 26 - Suspect Storage Area Connection Discharge Value

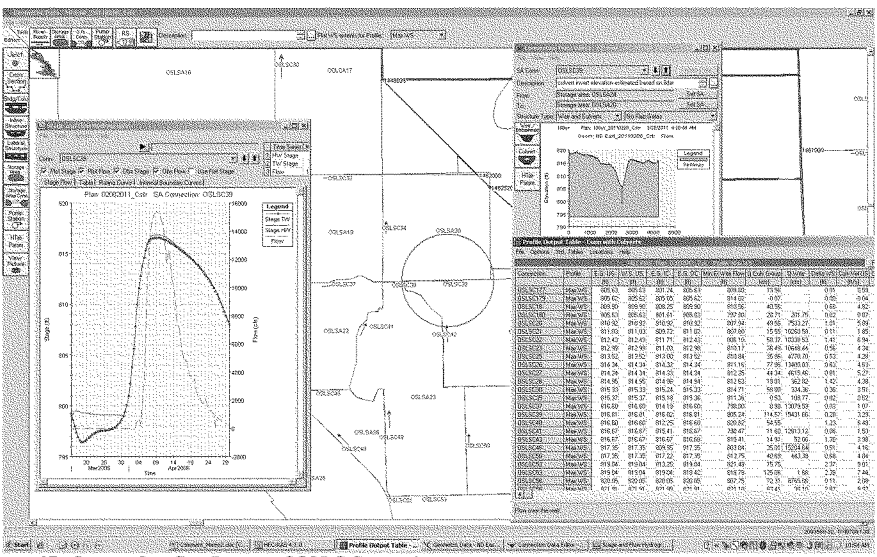

Figure 27 - Suspect Overflow Rates on OSOLC Connections

REVIEW 3. INTERNAL REVIEW BY HDR

50. Attached are some locations in the post-processing of the results that appear to be suspect. In Figure 28 and 30, the abrupt edges either mean that you have a roadway or other "levee-like" structure that is impounding the water or there is overflow that is not being accounted for. If it is an artificial impoundment, how will we ultimately need to treat an embankment of unknown integrity?

51. In other locations, the mapping shows areas of isolated ponding with no apparent way for water to get there (Figure 29). Those locations should be verified.

52. For the post-project condition upstream of the diversion (Figure 31), we will not be able to consider water contained by "levee-like" structures that are not compliant with 44 CFR 65.10 if we are increasing the water surface against those embankments. If there is a need to constrain the water at those locations, the project costs would need to include constructed levees at these locations that will meet FEMA's minimum standards.

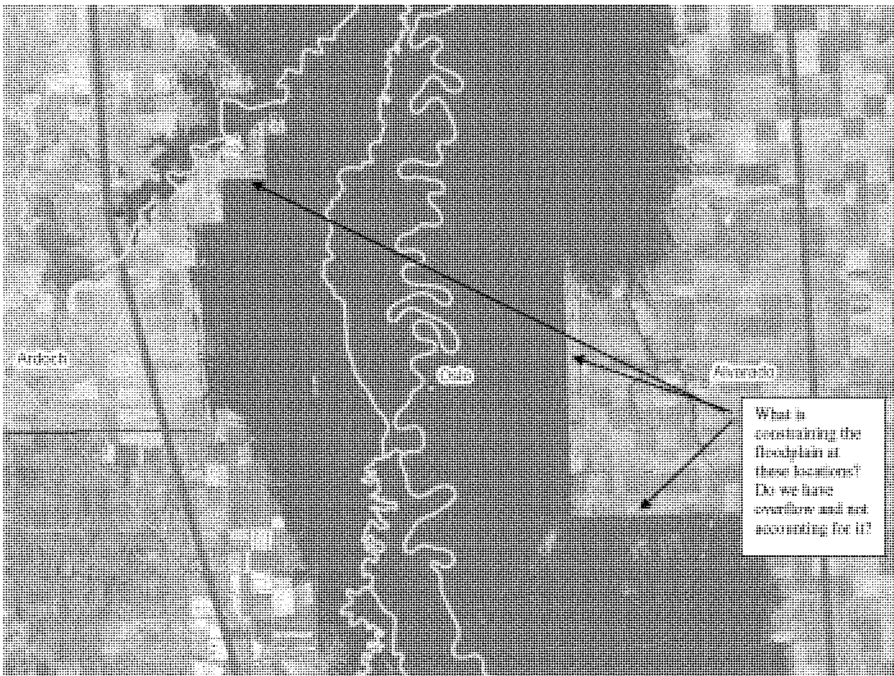

Figure 28 - 100-Year Inundation Limits

REVIEW 3 - INTERNAL REVIEW BY HDR

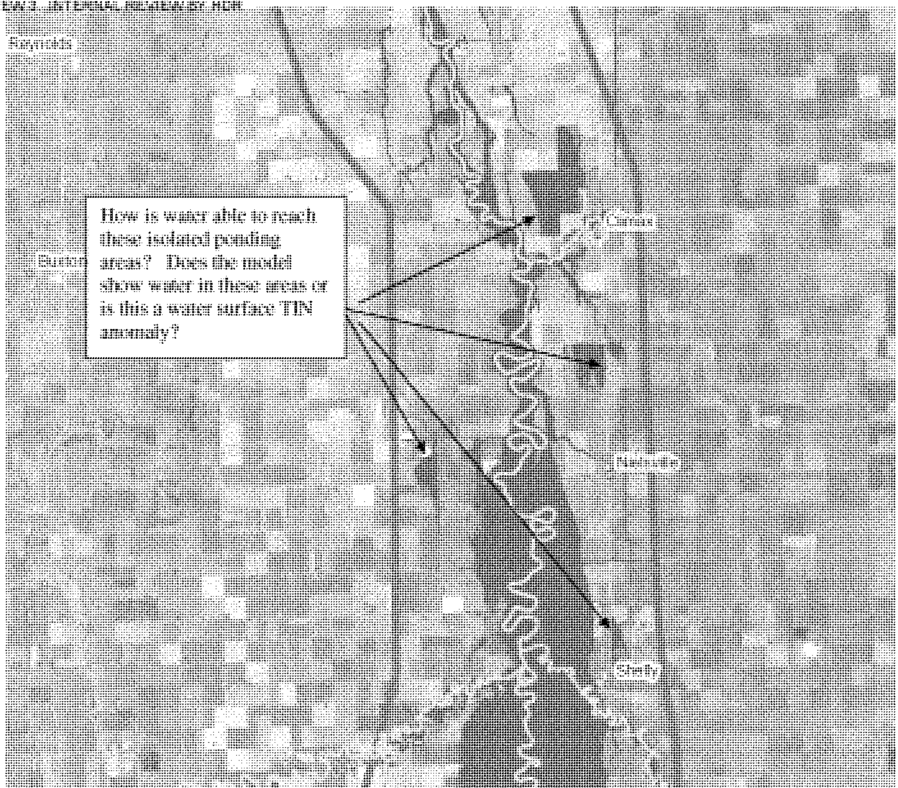

Figure 29 - 100-year Inundation Limits

REVIEW 1 - INTERNAL REVIEW BY HDR

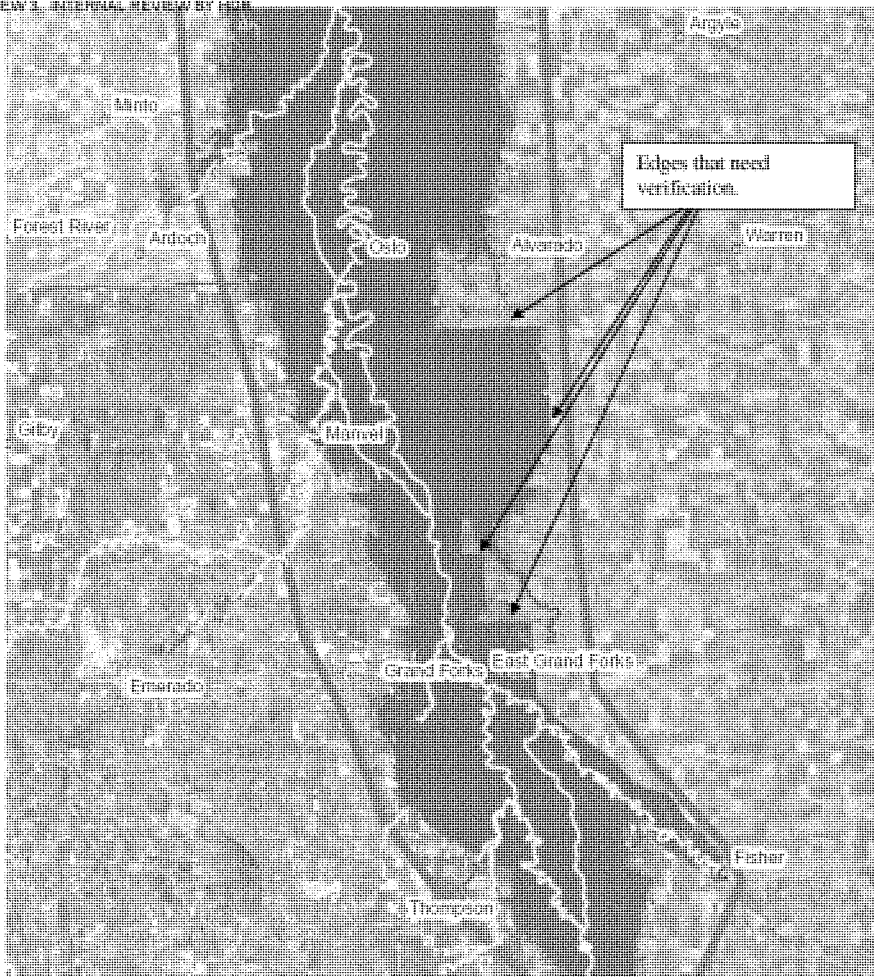

Figure 30 - 500-year Inundations Limits

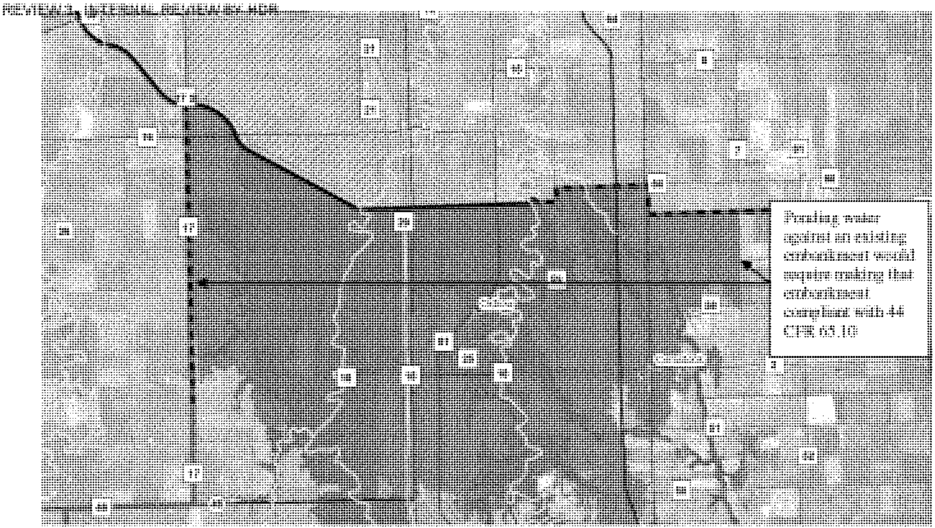

Figure 31 - 100-Upstream Post-Project Flood Limits

RED RIVER DIVERSION

FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4

APPENDIX C – HYDRAULICS WITH–PROJECT CONDITIONS

Report for the US Army Corps of Engineers, and the cities of Fargo, North Dakota & Moorhead, Minnesota

REVISED: April 11, 2011

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C1.0 RED RIVER DIVERSION - BACKGROUND AND OVERVIEW

C1.1 NEED FOR STUDY

The Red River has posed a repeated threat to the communities of Fargo, ND and Moorhead, MN as it has reached minor flood stage at 18 feet at least once each year since 1993. Although the communities have demonstrated significant ability in defending themselves against floods, the efforts can be massive and highly disruptive to the communities and their residents. Through the years, various flood protection plans have been formulated to protect portions of these communities and some of these plans have been developed and implemented to varying degrees. This study looks at the potential to develop a single comprehensive system to address flooding for the entire Fargo-Moorhead Metropolitan Area. Appendix A of this report covers the hydrology used in the modeling analysis for this study and Appendix B documents the development of the base condition unsteady flow models for this phase. This appendix, Appendix C, presents the unsteady flow hydraulic modeling and design of a Red River Diversion and its impacts on the Red River and its tributaries for the Locally Preferred Plan (LPP) with upstream staging. It also presents updated impact information for the Federally Comparable Plan (FCP) as presented in Phase 3.1 of the feasibility study.

C1.2 RELATED STUDIES AND PROJECT EVOLUTION

This report documents the fourth phase of the Fargo-Moorhead Metro Flood Risk Management Study-Feasibility Study. The first phase of the study began with a draft report issued by the United States Army Corps of Engineers (USACE) in March of 2009, and since that time multiple reports and updates have been published as the study has progressed. A summary of this progression is shown below:

Study Phase	Report Date	Hydrology Phase	Notes
Phase 1	March 2009	Phase 1	Draft Report March 2009 by US Army Corps of Engineers
Phase 2	August 2009	Phase 2	Initial work by Moore Eng. and Others
Phase 2	October 2009	Phase 2	Low Flow Analysis
Phase 2 Part 2	December 2009	Phase 2	Updated in January 2010
Phase 2 Part 2	January 2010	Phase 2	Northwest Diversion
Phase 3	May 2010	Phase 3	Hydrology updated for Wet and Dry cycles
Phase 3 (3.1)	July 2010	Phase 3.1	Hydrology amended, study limited to LPP and FCP
Phase 4	January 2011	Phase 4	Unsteady state design for LPP
Phase 4	February 2011	Phase 4	Update to January 31, 2011 Phase 4 report
Phase 4	April 2011	Phase 4	Update to February 28, 2011 Phase 4 report

For additional detail on how the discharges changed from Phase 1 through Phase 3.1, refer to Appendix A in the July 30, 2010 report. Attachment C1 of this report (Appendix C) contains an excerpt of pages A4 through A7 of the July 30, 2010 report. Consistent with the reports for previous phases, this report is meant to stand alone. It includes adequate information from previous reports, or specific references to the location of the information, in order to provide the reader with enough information to follow this report. Subsequent parts of this section of the report will provide a brief summary of the previous phases of this study.

C1.2.1 Ongoing FEMA Restudy. Since prior to the 1997 flood, FEMA has been in the process of updating the Flood Insurance Rate Map (FIRM) for the area of Cass and Clay counties in the vicinity of Fargo and Moorhead. Two studies in particular have defined the hydrology and hydraulics for much of the area along the Red River adjacent to the two cities. They include the "Stanley and Pleasant Townships, Cass County, ND and Holy Cross and Kurtz Townships, Clay County, MN Flood Insurance Study" (which was formerly referred to as "Flood Insurance Restudy for Southern Cass County, North Dakota, and Clay County, MN" in the Phase 3 report) (Reference A), which defines the hydrology and hydraulics for the area south of Fargo, and the "City of Fargo, North Dakota Flood Insurance Study" (formerly referred to as "City of Fargo CTP Project, Clay County/Oakport Township" in the Phase 3 report) (Reference B), which defines the hydrology and hydraulics through the Fargo-Moorhead area. The model developed by FEMA as part of these efforts served as the basis for hydraulic modeling on the Red and Wild Rice Rivers during the initial phase of the study.

C1.2.2 August 31, 2009 Report. In August 2009, a report entitled "Red River Diversion, Fargo-Moorhead Metro Flood Risk Management Project, Feasibility Study, Phase 2, Report for the US Army Corps of Engineers, and the cities of Fargo, ND & Moorhead, MN," (Reference C) was completed. That report looked at a variety of alternatives of sizing and flows for a Red River Diversion. Specifically, four alignments were considered around the Fargo-Moorhead (FM) Metro Area. Two of the alignments were considered on the Minnesota side. The Minnesota Long Diversion is the same alignment as the Minnesota Short Diversion downstream of a point west of Sabin, MN. Upstream of that location, the Minnesota Long Diversion alignment extends farther south to intersect the Red River at a location approximately three miles to the south. The two North Dakota alignments are also similar. The primary difference between the North Dakota West Diversion and the North Dakota East Diversion is the portion of the channel between Horace and West Fargo and how they utilize the existing right of way for the Sheyenne River Diversion. The East alignment was developed so that it closely followed the current Sheyenne River Diversion alignment within this area. Figure B1 in the August 2009 report provides a layout of the four alignments from this phase of the study. In addition to the four alignments, nine (9) options of flow in the Red River Diversion were considered. They include:

1. MN Short Alignment 45 Kcfs Alternative
2. MN Short Alignment 35 Kcfs Alternative
3. MN Short Alignment 25 Kcfs Alternative
4. MN Long Alignment 45 Kcfs Alternative
5. MN Long Alignment 35 Kcfs Alternative
6. MN Long Alignment 25 Kcfs Alternative
7. ND West Alignment 45 Kcfs Alternative
8. ND West Alignment 35 Kcfs Alternative
9. ND East Alignment 35 Kcfs Alternative

C1.2.3 Low Flow Modeling. In October 2009, a report on low flow conditions entitled "Appendix H - Red River Diversion Hydraulic Structure Velocities" (Reference D) was completed. This report was developed as an additional appendix to the August 31, 2010 report (Reference C). The purpose of this portion of the overall study was to gain a better understanding of the Red River under frequent flooding events smaller than the 50-percent chance (2-year) event. This analysis was particularly important in looking at fish passage. At this point in the study, the diversion inlet control weir was set higher than the 50-percent chance water surface elevation, so the diversion channel was not utilized for low flows and the Red River Control Structure was allowed to remain fully open. Therefore, the model used for this analysis only involved the main channel and the Red River Control Structure. The low flow events below the 50-percent chance event considered were:

1. 80% Exceedence or a 1.25-year recurrence
2. 90% Exceedence or a 1.11-year recurrence
3. 95% Exceedence or a 1.05-year recurrence
4. 99% Exceedence or a 1.01-year recurrence
5. 50 cfs which was estimated at 99.99% Exceedence

C1.2.4 December 31, 2009 (Updated January 6, 2010) Report. In December 2009, a report entitled "Red River Diversion, Fargo-Moorhead Metro Flood Risk Management Project, Feasibility Study, Phase 2, Part 2, Report for the US Army Corps of Engineers, and the cities of Fargo, ND & Moorhead, MN" (Reference E) was completed. That report updated the progress of the study and updated the hydrology to Phase 2 Hydrology. Phase 2 Hydrology was developed to update the Red River hydrology to incorporate the 2009 flood event. This report was further updated in January of 2010. As part of this phase of the study, the number of alignments was reduced to two, the Minnesota Short Alignment and the North Dakota East Alignment. No significant changes were made to the alignments from the previous phase. One of the goals with this phase was to determine the National Economic Development (NED) Alternative; therefore, several flow options were considered. These flow options were primarily for the Minnesota Short Alignment because the information presented in the August 31, 2009 report and the subsequent cost/benefit analysis clearly indicated that the NED plan would be associated with this alignment. The options on the North Dakota side were included at the request of the local project sponsors as this was their preferred alignment option. The flow options considered were:

1. MN Short Alignment 10 Kcfs Alternative
2. MN Short Alignment 15 Kcfs Alternative
3. MN Short Alignment 20 Kcfs Alternative
4. MN Short Alignment 25 Kcfs Alternative
5. MN Short Alignment 30 Kcfs Alternative
6. MN Short Alignment 35 Kcfs Alternative
7. ND East Alignment 30 Kcfs Alternative
8. ND East Alignment 35 Kcfs Alternative

C1.2.5 Northwest Diversion. In January 2010, a report was completed on the Northwest Diversion Alternative (Reference F). The Northwest Diversion Alternative was created as a means to deal with flooding north of Fargo and West Fargo from the Sheyenne River and its tributaries if a Minnesota Diversion Alternative was constructed. This diversion needed to consider not only a Red River flood but also local flooding from the Sheyenne River itself. The hydraulic model used for this part of the study used an unsteady model of the Red River and its tributaries, which was under development to look at downstream impacts of the project. The model was reduced to the portion dealing with the Sheyenne River system. The local flood events considered for this part of the study were the 10, 2, 1 and 0.2-pecent chance events.

C1.2.6 May 17, 2010 Report. In May 2010, a report entitled "Red River Diversion, Fargo-Moorhead Metro Flood Risk Management Project, Feasibility Study, Phase 3, Report for the US Army Corps of Engineers, and the cities of Fargo, ND & Moorhead, MN" (Reference G) was completed. That report updated the study progress and hydrology. Phase 3 Hydrology was developed as part of a need to look at the Red River hydrology as two dissimilar periods of record. One period of record was characterized as "Wet" while the other was characterized as "Dry". From these two records, hydrology was developed for the project year zero, project year 25, and project year 50. Project year zero has the greatest flow through the FM Metro with decreasing flows in the subsequent two project year time periods. Because of this, it was necessary to run models for each alternative and flow option for the three project time periods. Additional discussion on this aspect of the hydrology is provided in Appendix A – Hydrology of the May 17, 2010 report. As part of this phase, only two Red River Diversion alignments were considered: Minnesota Short Alignment and North Dakota East Alignment. With new hydrology, it was necessary to revise the NED analysis. The NED analysis focused on the Minnesota Short Alignment. The North Dakota East Alignment 35 Kcfs alternative was also considered due to being chosen as the Locally Preferred Plan (LPP). The flow options for the Red River Diversion considered during this phase were:

1. MN Short Alignment 20 Kcfs Alternative
2. MN Short Alignment 25 Kcfs Alternative
3. MN Short Alignment 30 Kcfs Alternative
4. MN Short Alignment 35 Kcfs Alternative
5. MN Short Alignment 40 Kcfs Alternative
6. MN Short Alignment 45 Kcfs Alternative
7. ND East Alignment 35 Kcfs Alternative

Following this analysis, the NED plan was determined to be the Minnesota Short Alignment, 40 Kcfs plan.

C1.2.7 July 30, 2010 Report (Phase 3 with Phase 3.1 Hydrology). With the May 2010 Phase 3 report, it was noted that Phase 3 Hydrology significantly increased the flows through Fargo, yet the flows further downstream, at locations such as Halstad and Grand Forks, did not increase significantly and were similar to values used in Phase 2 Hydrology. Further refinement of the hydrology, particularly with the Sheyenne River coincidental flows, resulted in improved results. Given the importance of the Sheyenne River on project parameters, a revision to the Phase 3 Hydrology was developed. Because this new hydrology did not represent a fundamental update but rather a smaller change, it was referenced as Phase 3.1 for the study. On July 30, 2010, a report entitled "Red River Diversion, Fargo-Moorhead Metro Flood Risk Management Project, Feasibility Study, Phase 3 (Phase 3.1 Hydrology), Report for the US Army Corps of Engineers, and the cities of Fargo, ND & Moorhead, MN" (Reference H) was published. This report included the updated project design information based on the Phase 3.1 Hydrology. For more details on Phase 3 and Phase 3.1 Hydrology, see Appendix A – Hydrology in the July 30, 2010 report. While the updated hydrology is the fundamental difference between this report and the May 17th version, minor revisions to the diversion alignments were also incorporated into the updates. At this point, the project was narrowed down to two alternatives. These two alternatives represent the Federally Comparable Plan (FCP) and the Locally Preferred Plan (LPP) plan, which were:

1. MN Short Alignment 35 Kcfs Alternative - FCP
2. ND East Alignment 35 Kcfs Alternative – LPP

After the July 30, 2010 report was released, the design of the FCP diversion channel was modified to account for updated geotechnical data provided by the USACE. These changes were completed and documented on August 11, 2010, but the revised report was not officially released. Although the revised design was never officially published, it is considered the FCP for Phase 4 of this study and the impacts and results included in the Phase 4 report are based upon the updated FCP diversion channel design. Because the modifications to the FCP design had not previously been published, Appendix B of the August 11, 2010 report has been included in this version of the Phase 4 study report as Attachment C2 in order to document the current FCP design. In short, the FCP diversion channel was modified due to concerns with hydrostatic water pressure potentially causing uplift on the bottom of the channel. To account for this, the channel bottom was raised four feet beginning at approximately 43rd Avenue North and extending south (upstream) to the inlet of the diversion channel. The slope of the channel bottom remained the same, but it was necessary to include a sheet pile and riprap drop structure to ensure channel stability at the location of the four foot drop. Downstream of this location, the channel remained unchanged from the original Phase 3 design. Upstream of this location, the channel was widened from 225 feet to 400 feet to account for the reduced channel capacity. For the reach between 43rd Avenue North and I-94, the side slope of the channel was flattened from 7:1 (H:V) to 10:1 (H:V) to address additional stability concerns. The current FCP alignment is shown in Figure C1. The project plan drawings included in Appendix D of the Phase 4 report provide typical cross sections for the FCP diversion channel as well as a more detailed plan view of the alignment.

C1.3 PHASE 4 SUMMARY

C1.3.1 January 31, 2011 Report. After the downstream impacts of the project developed in Phase 3 were analyzed, it was determined that they were not fully definable and another approach was needed. Following the consideration of multiple options, the USACE and local project sponsors decided to pursue an option that included raising the water levels, or staging, upstream of the FM Metro area. While this would impact homes and properties on the upstream side of the project, this option allows the impacts to be fully defined and there are fewer structures affected by shifting the impacts upstream and the mitigation measures are also less costly for the upstream staging option. In addition to utilizing the existing topography, much of which is already inundated by flooding, this concept would also include constructed storage areas, specifically an area identified as Storage Area 1 that would provide some control on the storage and subsequent release of the water to help with the timing and the impacts at peak flood stage. These concepts were incorporated into Phase 4 of the project. The initial analysis for this phase was documented in a January 31, 2011 report entitled "Red River Diversion, Fargo-Moorhead Metro Flood Risk Management Project, Feasibility Study, Phase 4, Report for the US Army Corps of Engineers, and the Cities of Fargo, ND & Moorhead, MN" (Reference I).

In order to develop a design that incorporates the benefits of the upstream storage and staging, the design for this phase required the use of unsteady state modeling techniques. Up until this point, unsteady flow models had only been used to analyze the impacts of the project designs that had been developed with steady state methods, which are simpler and less time intensive to use. Phase 4 involved extensive upgrades to the existing unsteady state existing conditions models followed by full project design utilizing these models to analyze the benefits of upstream storage and staging. This phase involved only the redesign of the Locally Preferred Plan (LPP), which is the North Dakota East Diversion. The design for the Federally Comparable Plan (FCP) completed in Phase 3, as discussed in Attachment C2 of this appendix, is adequate since the project impacts have been fully defined and upstream staging is not required to fully define these impacts. Therefore, no updates were completed for the FCP as part of Phase 4. The background information on the FCP design and other information on the alternatives on the Minnesota side of the Red River can be found in Attachment C2 and reports for earlier phases of this study. However, the FCP design was analyzed with the updated models developed for Phase 4 to evaluate the downstream impacts and the results were included in the report.

C1.3.2 February 28, 2011 Report. Following the review of the January 31, 2011 report and the completion of additional information that was not included in that report, most notably Appendix F, which details the structural design of the hydraulic structures, an updated version of the report was published on February 28, 2011. Appendix C of this report included documentation on the comments developed from the internal Quality Assurance/Quality Control (QA/QC) review and the responses to those comments. Also included in this version was some discussion on future updates and improvements that could be made to the models, most of which simply could not be completed on the timeline allotted for this phase. It should be noted that the results associated with the February 28, 2011 version of the report are different from those included in the January 31, 2011 report due to changes that were incorporated after the QA/QC review. The February 28, 2011 report was submitted for Agency Technical Review (ATR).

C1.3.3 April, 2011 Report Summary. Following the ATR review conducted on the February 28, 2011 Phase 4 submittal, the report was updated to account for the comments provided by the ATR reviewers. The comments on Appendix C were minimal and have been addressed within the April 11, 2011 version of the report. In addition to these changes, other updates were added to this version, most notably the inclusion of Attachment C2 which provides documentation on the design of the current FCP originally designed during Phase 3 of the project but never officially documented. The April 11, 2011 report will be the final documentation for the primary LPP and FCP analysis for Phase 4.

C1.3.4 Supplemental Studies. After the February 28, 2011 submittal for Phase 4 of the primary study, a supplemental study was commissioned by the local project sponsors to investigate alternative design scenarios for the LPP. These alternatives included larger or smaller configurations for Storage Area 1, the inclusion of additional storage areas, the elimination of storage areas with an increase in upstream staging and eliminating upstream staging by implementing the Phase 3 design. A scenario with the alignment of the diversion extended south to protect the Oxbow/Hickson area was also analyzed. The results of this supplemental study were documented in a report entitled "Red River Diversion, Fargo-Moorhead Metro Flood Risk Management Project, Feasibility Study, Phase 4, Alternative Scenarios Analysis, Report for the cities of Fargo, ND & Moorhead, MN" (Reference J) which was published on April 8, 2011.

C2.0 RED RIVER DIVERSION – HYDRAULIC DESIGN

C2.1 OVERVIEW

As stated above, prior phases of this study were completed with steady state modeling techniques, with subsequent unsteady state analysis completed in some instances to determine related impacts. With the project hydrology identified in Appendix A and a change in the design criteria stipulated for the Phase 4 design, unsteady state models are required in order to implement the upstream storage and staging aspects of the project into the design. Additionally, the unsteady flow models also provide a better representation of the flows through the floodplains and a better assessment of the contributions from the tributaries, with respect to timing and magnitude, to flooding within the Red River of the North floodplain. This was a fundamental change in the modeling effort and while some of the preliminary analysis could be completed with steady state models, the bulk of the design requires unsteady state models.

Prior to Phase 4, unsteady state models were being developed in a parallel effort with the project design. Those models were then used to analyze the diversion designs for downstream impacts. These unsteady state models provided a starting point for the models required for Phase 4, but an extensive effort was necessary to generate the necessary base condition models required to begin the design process. With nearly 900 storage areas and 2,000 cross sections, the resulting models are a large collection of interconnected storage areas, river reaches and junctions that utilize the most recent unsteady state hydrology data to reflect real world conditions to the greatest extent possible.

C2.2 MODEL HYDROLOGY

The Phase 3.1 design included three sets of hydrology, which were based on “wet” and “dry” hydrology scenarios covering project year zero, project year 25 and project year 50 (See Attachment C1). This data allowed for the project to be analyzed for the expected changes in hydrologic conditions over the life of the project. For each of these scenarios, the project designs were analyzed for the 20, 10, 5, 2, 1, 0.5 and 0.2-percent chance events. Additional analysis was also completed for lower flow conditions (events smaller than the 20-percent chance event), and for extremely large events such as the 0.1 and 0.01-percent chance events. The Phase 4 design is based only on the hydrology outlined in Appendix A of this report, which includes hydrology based on the “wet”, project year zero conditions.

C2.2.1 Design Event Hydrology. The Phase 4 design has been designed for only the 10, 2, 1 and 0.2-percent chance events, in all cases using the hydrology scenario corresponding to project year zero. The geometries for each return event are identical, but the gate operations for the control structures are adjusted to meet the flow criteria established for each structure and each design event.

C2.2.2 Historical Event Hydrology. In addition to the design events listed above, the project design was also analyzed to determine the impacts of the project based on the hydrology corresponding to selected major flood events that have impacted the project area. This analysis included the flood events from 1997, 2006, 2009 and 2010.

C2.2.3 Extreme Event Hydrology. The previous phases of this study included analyses of the design for extreme hydrology events. The Phase 4 design included modeling of the Standard Project Flood (SPF) for the determination of design elevations for certain structures and features. This effort is discussed in greater detail in Appendix F. A more detailed analysis, consistent with previous phases, was not completed for this report. Consideration should be given to this analysis in the future.

C2.2.4 Hydrology Inputs. The flow files used in the steady flow models for Phase 3.1 included initial flow values, flow splits at junctions, flow changes representing inflows from tributaries, and gate settings for structures included in the geometry. The flow files used in the models for Phase 4 represent unsteady flows, so they include flow hydrographs for various inflow locations throughout the model. The development of these hydrographs is discussed in Appendix A. In addition to the hydrographs and flow inputs for the entire model, the unsteady flow files for Phase 4 also include the gate settings and operations for the gated structures included in the geometry.

C2.3 EXISTING CONDITONS MODELS

The existing conditions models for Phase 4 were produced by Houston Engineering, Inc. (HEI). HEI had developed earlier versions of the unsteady state models used to analyze the previous diversion designs. These models underwent extensive updates due to the modeling needs presented in Phase 4, including the addition of hundreds of storage areas and the extension of the model downstream to Drayton, North Dakota and upstream of Hickson, North Dakota. The Sheyenne River and Maple River systems were also added to the models. The updated models were completed through collaboration with other members of the design team- USACE, Moore Engineering, Barr Engineering and HDR Engineering- with support provided for GIS analysis, hydrologic modeling and peer reviews. HEI has documented the development of these models in Appendix B.

C2.3.1 Reference Model. The existing conditions models discussed above include separate geometry files representing conditions with and without emergency protection measures in place within the project area. These emergency measures would be structural barriers like clay levees, sand bag levees and flood walls that were used by the communities for protection during actual flood events. The existing conditions models were calibrated to measured high water marks during historic flood events. Because the emergency measures were in place during the historical flood events, they had to be reflected in the geometry used in the models in order to get an accurate calibration. After calibration, the emergency levees were removed to produce the geometry for the unprotected condition. The impacts of the project were determined by comparing the with-project models to the existing condition models without emergency measures in place. This allows for the determination of the full benefits of the project by comparing it to the damages that would be incurred if nothing was done to protect the communities. All impacts presented in this report reference the "without emergency protection" condition for both existing and with-project conditions.

C2.4 WITH-PROJECT CONDITIONS MODELS

The design for Phase 4 of this study involved new aspects, namely storage cells and staging upstream of the FM Metro area, which could not be properly accounted for with the steady state models that had been used in the previous phases. Refer to Figure C1 for a map depicting the staging and storage areas in the model. The design and subsequent impact analysis for this phase is based on the unsteady state existing conditions models developed by HEI. The development of the existing conditions models was a massive and intensive effort. Given the limited amount of time that was afforded to this phase of the study, the design and impact analysis had to proceed concurrently with the baseline model development. This required a coordinated effort to ensure that all of the updates to the baseline models were also included in the with-project model. While the design for Phase 4 shifted to an unsteady state methodology, the premise behind the design for the diversion channel and the associated hydraulic structures remained essentially the same. The addition of the upstream storage and staging added additional components to the design, but they simply resulted in different design discharges for the diversion channel and structures.

<u>C2.4.1 Model Modifications.</u> Once a preliminary baseline model became available, the process of modifying it for inclusion of the project design components was started. The major modifications to the models are discussed below:

1) The most extensive effort required was the modification of the storage areas along the diversion alignment to allow for the diversion geometry to be merged with the model. Utilizing GIS and HEC-RAS capabilities, a corridor of sufficient width to accommodate the diversion channel and spoil banks was cut through the storage areas included in the model. Some storage areas were split into two smaller areas and some resulted in one smaller storage area. After this was completed, the storage area connections were adjusted to reflect the changes.

2) The upstream storage areas identified for the project design were incorporated into the model along with the associated connections.

After the channel corridor was put in place and the storage areas were modified, the geometry for the new diversion channel was incorporated into the model. Due to the amount of time required for the unsteady state simulations to be completed, utilizing these models for optimizing the diversion channel design would not have been efficient, especially considering the timeline for this phase of the project. As the unsteady state baseline models were being modified as discussed above, a steady state model was created to generate an initial diversion design that could be inserted into the unsteady state model for further refinement. Assumptions were made for flow inputs at various reaches along the diversion and the hydraulic structures were simplified at this stage of the design. A summary of the steps taken to incorporate this preliminary geometry into the unsteady flow model are included below:

1) Junctions were established at the upstream and downstream ends of the diversion at the Red River of the North.

2) Lateral weirs and storage area connections were added or modified to connect the storage areas with the new diversion channel. The existing lateral weirs and connections associated with the Horace/West Fargo Diversion were also modified or deleted so that they were not connecting to storage areas they no longer contributed to due to the new diversion.

3) The hydraulic structures at the Maple River, Sheyenne River and Wild Rice River were added, including provisions for the pass through flow into the protected areas and the connections for the flow diverted into the diversion.

4) Hydraulic structures and culverts for the smaller tributaries (including those at the Lower Rush River and Rush River) were added to the model, with most of them including measures to prevent backflows from the diversion into the adjacent storage areas.

<u>C2.4.2 Model Stabilization.</u> After the geometry was set up as detailed above, attempts were made to get the preliminary with-project model to run. What followed was a repetitive process of run attempts and subsequent improvements to the models to correct instabilities. Many storage areas had to be adjusted to account for the upstream staging and some storage-elevation curves had to be adjusted to account for culverts and weirs that were added to storage area connections. These changes were documented so that necessary changes could be made to the baseline models as well. Likewise, the latest updates generated by HEI for the existing condition models were worked into the with-project models throughout the entire process. Through these efforts, the model was eventually stabilized and allowed to progress through the entire simulation process.

<u>C2.4.3 Initial Design.</u> After the model was able to run completely, the preliminary project design developed with the steady state models was analyzed to see where the design needed to be adjusted for the project to meet the design objectives. From this initial unsteady flow model, numerous models were developed and run to design specific project components and to analyze various design scenarios, many of which were an attempt to reach a balance between the downstream impacts and the impacts of the storage and staging upstream. The goal was to release enough water from the upstream storage areas through the diversion to produce water surface elevations in the Red River downstream of the diversion that were equal to (or slightly lower for conservatism) than existing conditions while meeting the stage elevations targeted at the Fargo gage in Phase 3. This would result in the maximum level of upstream staging required to mitigate the downstream impacts without providing actual benefits to the downstream reaches. The

aspects of the project that underwent extensive analysis throughout the development of the project during this phase are discussed in the following sections.

C2.5 ALIGNMENT

The North Dakota Diversion (LPP) diverts water from the Red River, Wild Rice River, Sheyenne River, Maple River, Lower Rush and Rush Rivers and numerous legal drains to a location downstream of the mouth of the Sheyenne River. A map showing the alignment and the project area is shown in Figure C1. The alignment has remained largely unchanged from its initial layout. The background information on the development and previous changes to the alignment can be found in the reports for first three phases of this study.

With the Phase 4 design, some modifications were made to the North Dakota Diversion (LPP) alignment, although they do not have a sizeable impact on the project. The north end of the alignment was adjusted near Argusville to avoid interference with Drain 13. It was determined that Drain 13 was already an efficiently functioning legal drain so it could be utilized for its capacity separately from the diversion. The alignment was shifted to the south and east to accommodate this change. In other areas, minor changes were also incorporated where existing homes and buildings could be reasonably avoided. The existing Horace Diversion channel will be incorporated into the LPP diversion channel so the alignment was adjusted so that the east side of the LPP diversion matched the east side of the existing Horace Diversion channel. The Horace Diversion reach was removed from the HEC-RAS model.

C2.6 CHANNEL SIZING

The diversion channel geometry for Phase 4 was determined based on hydraulic capacity and then modified based on geotechnical analysis at various reaches along the diversion. The sizing of the channel considered the cross section geometry, channel slope and channel bottom invert elevations to determine the optimal channel design. A change in any one of these three design components affects the other two. The optimal channel design has to result in a 1-percent chance water surface profile within the diversion that does not exceed the target elevation established by the Corps in previous phases, which was based on maintaining the 1-percent chance profile below existing ground in most locations. This generally involves an iterative process to analyze a series of combinations before the optimal design is determined.

<u>C2.6.1 Channel Bottom Invert Elevations.</u> The channel bottom elevations for the North Dakota Diversion (LPP) alignment are directly related to the channel slope and the cross section geometry, but there were some additional design constraints on the elevations at certain locations. The most important constraint was the minimum height of the opening under the aqueduct structures at the Maple and Sheyenne Rivers. The USACE requested that the designs for these two structures include a minimum opening of six feet between the bottom of the low flow channel (the low flow channel is expanded to the full width of the aqueduct opening) and the low chord of the aqueduct, which is a fixed elevation

based on the bottom elevation of each tributary. Thus, six feet was subtracted from each low chord elevation and the minimum bottom elevation of the low flow channel in the diversion was established at each location. A constant slope between the two aqueducts was desired, such that additional structures would not be required to incorporate grade changes or channel drops and the associated costs and operational issues could be avoided. The design of the Maple River aqueduct produced an optimal opening height of seven feet. The slope created between bottom of this opening and the six foot opening at the Sheyenne River was deemed to be too steep (see discussion in Section C2.6.2) and a maximum slope of 0.015% was selected in conjunction with the cross section geometry. This resulted in an opening height of 13 feet at the Sheyenne River structure.

C2.6.2 Channel Slope. The North Dakota Diversion (LPP) alignment channel bottom slope was set at a constant slope of 0.015% downstream of the inlet control weir. This was a change from the constant slope of 0.02% that had been included in the design from Phase 1 through Phase 3. As discussed above, the bottom slope was developed along with the bottom elevations and cross section geometry. The 0.015% slope resulted in slower channel velocities than the previous 0.02% profile, which helps reduce the downstream impacts because the timing is adjusted enough that the peak discharges from the diversion and the Red River do not coincide as closely as they did with the Phase 3 design. For the reach between the Wild Rice River and the inlet control weir, the channel sloped toward the inlet control weir for Phases 1 through 3 and for the January 31, 2011 Phase 4 design. For the final Phase 4 design, the channel has been designed to slope from the inlet weir back to the Wild Rice River at 0.005% grade. This reach runs within the staging area so it is not required to convey large flows during larger flood events because the entire area is inundated. Reversing the flow direction for low flow conditions eliminated issues with the low flow outlet to the lower channel bottom downstream of the inlet weir and the amount of hydraulic head present during large events. Figure C6 provides a profile from the HEC-RAS model for the North Dakota Diversion.

C2.6.3 Channel Cross Section. The basic cross section geometry for Phase 4 was determined based on hydraulic capacity and then modified based on geotechnical analysis at various reaches along the diversion. After selecting a bottom profile, the unsteady state models representing with-project conditions were utilized to size the channel. A simple trapezoidal channel with 7:1 (H:V) side slopes was iteratively widened until the 100-year water surface profile in the diversion matched the target elevation established by the Corps. A channel with a bottom width of 250 feet was determined to be the appropriate design for Phase 4, based on the following criteria: (1) allowed design to meet goal of zero impacts downstream; (2) allowed design to meet targeted 1-percent chance profile in the diversion channel; (3) did not increase the volume of excavation with respect to other (wider bottom width) options; (4) resulted in a channel with invert elevations above the Brenna formation for a significant length of the diversion alignment. After this determination was made, the design was forwarded to the Corps for geotechnical analysis on the stability of the channel. The Corps' geotechnical analysis called for benching in five sections along the diversion alignment. The benches were all set at eight feet above the bottom of the main channel and varied in width from 15 to 40 feet. The side slopes above and below the benches all remained at 7:1 (H:V) throughout the length of the diversion. The low flow channel included in Phase 3, which had a depth of three feet, 4:1 (H:V) side slopes and a 10 foot bottom, was also incorporated into the channel geometry. The cross section geometries for the diversion are summarized in Table C1. As discussed in Section C2.6.2 above, the size of the channel in the reach between the Wild Rice River and the diversion inlet weir was reduced for the final Phase 4 design. Within this reach, the channel has a 100 foot bottom and 7:1 (H:V) side slopes. A typical section for the connection channel between the Wild Rice and Red Rivers is shown in Figure C3 and a typical section for the diversion reach between the diversion inlet weir and the Wild Rice River is included in Figure C4. A typical section for the remainder of the diversion is included in Figure C5. Note that these figures reflect a pilot channel extending below the low flow channel. The pilot channel was added to the diversion channel for model stability purposes only and will not be included in the constructed diversion channel.

C2.7 RED RIVER TO WILD RICE CONNECTING REACH

The North Dakota Diversion (LPP) design continues to pull water from both the Red River and the Wild Rice River through a connection channel between the two rivers. With the inclusion of upstream storage and staging in the Phase 4 design, this channel also serves as an outlet to drain the water from these areas. The levees and spoil piles on the south side of this channel will be constructed to elevations that will allow water to freely enter the connection channel from the storage areas. Similar to the design for previous phases, this channel slopes in the opposite direction of the diversion channel with the bottom sloping from the Wild Rice River to the Red River at a 0.02% grade. This prevents water from flowing from the Red River into the diversion during low flow events and allows the local flows to drain to the Red River under low flow conditions as well. As flood stages rise during larger flood events, the flows are able to overcome the adverse slope and make their way west and down the diversion. A control weir on the east side of the Wild Rice River prevents water from discharging from the Wild Rice into the connection channel and into the Red River for low flows. The channel bottom invert at the connection with the Red River is much higher than the bottom of the Red River, so erosion protection is necessary to allow local flows to drain back to the Red River without causing erosion and stability problems when the Red River is lower than the bottom of the connection channel.

C2.8 UPSTREAM STORAGE

The most significant change with the Phase 4 design was the inclusion of storage and staging on the upstream side of the project. This aspect of the design was created by adjusting the operation of the control structures on the Red River, Wild Rice River and Wolverton Creek to back water up behind them and by allowing less water down the diversion through the diversion inlet weir (which was sized considerably smaller than in Phase 3). This forces water levels to build up, or stage, over the land upstream. Much of the land impacted by this staging was already inundated with flood waters under existing conditions, but the forced staging raises the 1-percent chance flood stage about seven feet at the Red River Control Structure. In addition to the mitigation required to offset the impacts to homes and properties within the staging area, the control structures and levees creating the boundaries for the protected area had to be elevated safely above the staging elevations. In addition to the staging on areas outside (upstream) of the protected areas, a large storage area, designated as Storage Area 1, was included in a location that had been within the protected area. This area is located west (downstream) of the Wild Rice River and the approximate boundaries are formed by Interstate 29 on the east, County Road 14 on the north and County Road 17 on the West. The diversion channel abuts the south side of the storage area and water is allowed to flow in and out of storage from the diversion. The inflows and outflows are controlled by a weir to allow for some control on the timing of these flows to provide the greatest benefit in reducing peak flows downstream. The crest of this weir is 1,400 feet wide and is set at an elevation of 910.0.

C2.9 TIE-BACK LEVEES

The tie-back levees required for the North Dakota Diversion (LPP) plan for Phase 4 required some significant changes due to the inclusion of the storage and staging upstream of the diversion. The levee alignment on the Minnesota side begins at the Red River Control structure and runs east, just as it did with the Phase 3 design. With the levees being raised approximately seven feet due to the staging included in Phase 4, the levees were extended to a length of about six miles until they reached far enough east to tie into natural ground. On the North Dakota side, a tie-back levee was implemented on the east side of Cass County Highway 17 to prevent water from breaking out to the west and bypassing the proposed diversion inlet control weir. This levee runs from the diversion channel south to until it ties into high ground about a half mile north of State Highway 46, which runs along the Cass/Richland County line. This tie-back levee helps define the storage and staging area being utilized upstream of the diversion. The top of this levee will be set at an elevation that will allow events larger than the 0.2-percent chance (500-year) event to over top the levee and flow west without overtopping the levee on the north side of the diversion channel and entering the protected area. Refer to Appendix F for further discussion on the design of the tie-back levees and associated features.

C2.10 NORTH DAKOTA TRIBUTARY HYDRAULIC STRUCTURES

The North Dakota Diversion (LPP) alignment intersects many tributaries, thus requiring significant hydraulic structures to allow some of the flow from the tributaries to continue flowing beyond the diversion and into the protected area. The structures proposed in the Phase 4 design are very similar to those included in Phase 3. Appendix F of this report provides greater detail on the designs for the hydraulic structures included in the project. In some locations, such as the Rush and Lower Rush Rivers, the tributaries are completely diverted into the diversion channel and the tributaries do not continue into the protected area. At other locations, namely the Maple and Sheyenne Rivers, aqueducts are required to allow the tributaries to flow over the top of the water flowing in the diversion. These structures allow enough water into the protected area to maintain the environmental integrity of the streams and aquatic ecosystems without causing major flooding. During larger flood events, a majority of the tributary flow gets diverted into the diversion channel.

C2.10.1 Minimum Downstream Flows. As discussed above, the USACE established a design stipulation during Phase 2 of this project that a minimum flow be maintained in each tributary as it flows through the protected area. This requirement was put in place to ensure that an adequate amount of flow was provided to maintain the environmental integrity of the streams and aquatic ecosystems. At that time, this flow requirement was set equal to the 50-percent chance local flow in each tributary. With the diversion alignment intersecting multiple tributaries, aqueducts are required to pass this required flow over the top of the diversion and into the protected area. In the cases of the Rush and Lower Rush Rivers, it was acknowledged that the natural setting corresponded to overland flow and that the current configuration was artificially created by channelization projects completed by USACE several decades ago. These tributaries would be allowed to be completely diverted into the diversion. In order to account for this flow and ensure adequate flow in the Sheyenne River, the 50-percent chance flow amount for these two rivers was added to the amount set on the Maple River. In other words, the minimum amount to pass through to the downstream reach of the Maple River would be the sum of the 50-percent chance local flood flows of the Maple, Lower Rush, and Rush Rivers. The minimum pass through flows for the Sheyenne River remained consistent with the 50-percent chance local flow. With the Phase 3 design, the Wild Rice River minimum flow was set as the coincidental flow associated with the 20-percent chance flow of 9,600 cfs on the Red River at the Fargo USGS gage during Phase 2. This coincidental flow amount for the Wild Rice River was approximately 2,350 cfs. The Phase 4 design utilizes a variable gate operation which results in a variable discharge through the gates and into the protected area. Although the revised hydrology incorporated with Phase 3 and Phase 3.1 resulted in higher flows for each design event, the minimum flow requirements were left at the values set in Phase 2 because that level of flow was still deemed adequate to maintain the environmental integrity of the streams. Similarly, these values were referenced as the target pass through flows for the Phase 4 design. This concept is further discussed in Appendix F.

C2.10.2 Wild Rice Hydraulic Structure. The Wild Rice River structure is similar to the concept presented in Phase 3. The river intersects the diversion channel at-grade, allowing the water in both channels to intermix. A gated control structure on the downstream side of this junction limits the amount of water allowed to enter the protected area. A weir structure east of the Wild Rice River prevents low flows from flowing east down the connection channel to the Red River. This weir is discussed in further detail in Section C2.11.1. On the west side, natural ground elevations and the invert of the diversion channel prevent low flows from flowing west down the diversion channel. High flows from the Wild Rice will merge with high flows entering from the Red River and all flows that cannot pass through the gated control structure will flow west and down the diversion channel to the diversion inlet control weir.

C2.10.3 Sheyenne River Hydraulic Structure. The hydraulic structure at the Sheyenne River is an aqueduct. The North Dakota Diversion flows under the Sheyenne River at this crossing. The flows in the diversion pass beneath the aqueduct through an opening that resembles a series of large box culverts. The opening is 13 feet high with a total width of 240 feet. Above this opening, the Sheyenne River runs perpendicular to the diversion channel through an open concrete channel carrying the targeted amount of flow into the protected area. The excess flows in the tributary are diverted into the diversion channel through a weir structure before reaching the aqueduct.

C2.10.4 Maple River Hydraulic Structure. The Maple River hydraulic structure included in Phase 3 was designed to allow water flowing in the diversion to pass both under and over the top of the aqueduct carrying the Maple River flows into the protected area. With changes to the hydrology and design features associated with Phase 4, water in the diversion no longer flows over the top of the aqueduct. With water no longer overtopping the aqueduct, control gates are no longer needed to restrict the amount of flow entering the protected area. With these changes, the Maple River structure now functions in the same manner as the Sheyenne River structure discussed above. The opening in the diversion channel is seven feet tall and 250 feet wide.

C2.10.5 Rush and Lower Rush Rivers. The Rush and Lower Rush rivers discharge into the diversion channel in the same manner as they did with the Phase 3 design. The two rivers enter the diversion through separate drop structures that direct 100% of the flow in these tributaries into the diversion. Without an aqueduct in place to carry some of the tributary flow into the protected area, additional water is allowed to enter the protected area through the Maple River aqueduct to make up for the lack of flow reaching the Sheyenne River. See Section C2.10.1 for additional discussion on downstream flows for the Maple River.

C2.10.6 Minor Tributaries, Legal Drains and Storage Areas. The project includes diversion inlet structures for smaller tributaries and legal drains that intersect the diversion, namely Cass County Drain 14 and Cass County Drain 21c. The models created for Phase 4 also reflect the intercept culverts that will allow the adjacent lands, which are reflected as storage areas in the models, to drain into the diversion. These intercept culverts are sized for the contributing watershed and include flap gates to prevent water from the diversion backing up through the culverts, similar to those on the existing Horace/West Fargo Diversion. The inlets between the Maple and Sheyenne Rivers have been sized to maintain the existing conditions 100-year floodplain associated with the independent peak flows from these tributaries. Maintaining the existing conditions floodplain was a requirement of environmental agencies reviewing the project. Further study and design is necessary to fully address this issue. Appendix F includes discussion on what has been completed to date and will be completed in the future.

C2.11 LPP DIVERSION STRUCTURES

In addition to the hydraulic structures implemented to handle the junctions with the diversion and the tributaries, there are other structures included within the diversion channel to control the water once it is flowing in the diversion. These structures include control weirs, drop structures and outlet structures, which are discussed below. Refer to Appendix F for more detailed discussion on these structures.

C2.11.1 Diversion Control Weirs. With the Phase 3 design, the two weirs included at the Wild Rice River structure not only controlled when water was allowed to leave the Wild Rice, but they also control when water is allowed to flow through the diversion. The crest of the west weir was set one foot higher than the east weir and served as the control weir for the diversion by limiting how much water could enter it. The crest elevations for these weirs were originally set during Phase 2 when the east weir was set at the Red River 20-percent chance (5-year) flood elevation and the west weir was set at the Red River 20-percent chance flood elevation plus one foot. This ensured that the diversion was not put into use prior to exceeding a Phase 2 Hydrology 20-percent chance event on the Red River. The flow that was associated with the 20-percent chance event was 9,600 cfs downstream of the confluence of the Red and Wild Rice Rivers. This flow level was established as a minimum flow to maintain in the rivers for environmental considerations. During Phase 3, rather than establishing minimum flows based on local flow events, the 9,600 cfs flow was maintained as the benchmark. This flow is equal to approximately a 28-percent chance (3.6-year) flow on the Red River downstream of the Wild Rice River confluence with the Phase 3.1 Hydrology. Based on this target flow, the east weir was left at the 28-percent chance flood elevation and the west weir was set one foot higher. With Phase 4, the targeted Red River flow through Fargo-Moorhead remained at 9,600 cfs and the crests of the weirs were adjusted based on the elevation associated with the 9,600 cfs discharge in the unsteady flow model. The crest elevation of the east weir at the Wild Rice River was lowered to 902.25, one foot lower than the crest of the diversion control weir.

The upstream storage and staging areas incorporated on the upstream side of the project extend west to a point within a few miles from the Sheyenne River. These areas are filled with water by holding back the water being discharged down the diversion. This is accomplished by placing a control weir within the diversion at the downstream end of the storage area. This weir works with the tie-back levees to retain the floodwaters in the desired storage and staging areas. By restricting the flow being discharged down the diversion channel, this control weir acts in the same capacity as the control weir that was placed on the west side of the Wild Rice River in the Phase 3 design. With the staging component included in the Phase 4 design, the control weir near the Sheyenne creates a pool from the weir all the way upstream to the Wild Rice River and beyond. This negates the need for a large scale control weir at the Wild Rice River and because the diversion channel design now prevents low flows from leaving the river channel, the Phase 4 design no longer includes a weir immediately adjacent the west side of the Wild Rice River. The primary inlet control weir designed for Phase 3 was multi-tiered with very wide openings. Due to the amount of water being staged above the weir in Phase 4 and the added hydraulic head it provides, the control weir was reduced to a single opening with a width of 90 feet. With the design incorporating the unsteady flow modeling, the crest elevation was adjusted to 903.25 to allow the diversion to begin operating when the target flow of 9,600 cfs was reached at the Fargo USGS gage. An initial analysis for the 1-percent chance event was conducted which raised the diversion inlet weir up to an elevation of 914.25. The purpose of this was to identify whether there would be any benefit by allowing more volume from the rising limb of the flood hydrograph to be retained in the staging area. However, it was found to provide no additional benefit for the 1-percent chance event.

This structure also coincides with a significant drop in the bottom of the diversion channel. The upstream storage reduced the diversion discharges enough that the size of the channel was significantly reduced from the Phase 3 design. The channel was raised upstream of the control weir to reduce the capacity, but it had to be dropped downstream of the weir to ensure that there was an adequate opening under the Sheyenne River aqueduct. Instead of having a separate drop structure and a control weir, the two were joined together at the location of the control weir at the downstream end of the staging area.

C2.11.2 Channel Outlet. The designs associated with previous phases of this study did not include considerations for a significant hydraulic structure at the outlet of the diversion channel at the junction with the Red River. The bottom of the diversion channel was close enough to the bottom of the river channel that a concrete drop structure was not warranted and a riprap grade control structure would be implemented if necessary. As noted in Section C2.6, the bottom slope and channel bottom inverts were modified with the Phase 4 design and the invert at the downstream end was raised about nine feet. This additional drop brought the total height differential between the diversion channel and the river bottom to about 17 feet. To account for the potential erosion issues that may result with this much drop at the outlet, a concrete hydraulic drop structure is included in the Phase 4 design. Although this structure may be adequately submerged by high water elevations on the Red River during many of the flood events, the continuous discharges from the Rush and Lower Rush Rivers, amongst other regularly contributing sources, would present cases where water is being discharged from the diversion channel while the Red River is considerably lower. In these cases in particular, a concrete drop structure is necessary to protect the diversion channel from head cutting and erosion.

C2.12 RED RIVER CONTROL STRUCTURE

The design of the Red River Control Structure remains the same as the Phase 3.1 design, with the exception of the top of the structure being raised to account for the increased water surface elevations associated with the upstream staging. This structure is a combination earthen berm and concrete structure with three gated openings that are utilized to regulate the amount of flow allowed to pass into the protected area. These gates, along with the diversion control weirs, control the head conditions and produce the desired staging elevations upstream of the structure as well as the target elevations within the protected area. With the steady state design methodology used in previous phases, the gate opening configurations for each design event were static, meaning that they did not change throughout the model simulation. The steady state model implies that the flows in the model are constant and the flow conditions upstream and downstream of the structure do not change over time. Based on this condition, the gate configurations were set to produce the desired flow conditions at the peak conditions produced by the Phase

3.1 hydrology. As previously discussed, the Phase 4 design is based on unsteady state modeling, meaning that the flow conditions are continually changing throughout the model simulation. As the hydrographs being routed through the control structure rise and fall, the hydraulic head conditions change accordingly and the same gate configuration can yield different results. For this reason, the design for Phase 4 utilizes a variable gate operation in the unsteady flow HEC-RAS model capable of accounting for the change in headwater and tailwater conditions to maintain the desired discharges through the structure. This process is discussed in greater detail in Appendix F. The minimum pass through flow targeted for the Red River Control Structure was approximately 7,250 cfs, which combined with the flow in the Wild Rice River to produce a discharge of 9,600 cfs at the Fargo USGS gage, as discussed in Section 2.10.1. The gate operations were designed to result in stages at the Fargo USGS gage (Red River RS 2388233) that closely matched the target elevations determined in Phase 3. These target elevations are shown in the following table:

Frequency	Water Surface Elev.* (ft)	Stage (ft)
10%	891.99	29.25
2%	892.74	30.00
1%	893.40	30.66
0.2%	902.66	39.92

*NAVD 88 Datum

C2.13 WOLVERTON CREEK CROSSING

As the hydrology for this study has progressed, the amount of flow being attributed to the Wolverton Creek tributary has increased and the design for the control structure on this tributary has changed accordingly. This structure allows flows from Wolverton Creek to pass into the protected area through the tie-back levee that extends east from the Red River Control Structure into Minnesota. With the inclusion of upstream staging, the structure also works with the structure on the Red River and the diversion inlet weir to impound water over the staging area. This structure includes two 10 ftx10 ft openings that are controlled by gates that are capable of regulating the flows into the protected areas. Without gates on this structure, the water impounded by the diversion control weir and the Red River Control structure would be able flow freely into the protected area. The flows from Wolverton Creek join with the flow immediately downstream of the Red River Control Structure and the flows in the Wild Rice River to produce the total discharge at the Fargo USGS gage. The gates on this structure are operated to ensure that the combination of these three flows results in the targeted stage the Fargo gage. Additional detail on this design included in Appendix F of this report.

C2.14 HYDRAULIC STRUCTURE MODELING

The Red River Control Structure is modeled as an inline structure with gates. The Sheyenne River and Maple River hydraulic structures were modeled as bridges within the diversion geometry, while the aqueducts for the tributaries passing over the diversion were reflected in the geometry for the tributary cross sections. Lateral weirs were incorporated into the model to reflect the side weirs that will divert water from the tributaries into the diversion at these locations. Lateral weirs were also used to implement the drop inlet structures at the Rush, Lower Rush and other tributaries that do not cross the diversion channel. The Wild Rice River is modeled through a combination of inline structures and lateral structures that reflect the control gates on the river and the side weirs on the diversion. The diversion inlet control weir is included in the model as an inline structure. Separate modeling of the hydraulic crossings was conducted to refine the designs. It should be noted that the geometry for the North Dakota Diversion (LPP) alignment for Phase 4 does not include the bridge crossings that were included in the Phase 3 design for the roadways that will cross the diversion. It was determined that the channel cross sections would not be modified through the bridge openings and the low chord elevations of the bridges would be elevated above the 0.2-percent chance water surface elevations in the diversion channel. The only impedance at the bridges would be caused by the piers extending up from the bottom of the channel to support the bridges. A sensitivity analysis was completed to determine the influence of the bridge piers on the modeling results, and it was determined that the piers did not affect the modeling results on the Red River of the North. Within the diversion channel, the maximum impact of the bridge piers was 0.18 feet with a typical impact of 0.10 feet at most locations. With no significant impact on the design, the bridges were excluded from the model geometry to simplify the modeling effort.

C2.15 INTERNAL MODEL REVIEW

The unsteady flow models developed during Phase 4 of this study underwent a series of Internal Quality Assurance/Quality Control (QA/QC)) reviews conducted by members of the consultant's team. The members of the Internal QA/QC Team consisted of reviewers that were part of the design team and reviewers that were independent of the design team. The existing conditions models developed by Houston Engineering were reviewed by the other three firms on the team and most of the comments were addressed in the final models. The comments and responses developed during the review of the existing conditions models are documented in Appendix B of this report. The with-project models for the LPP design were primarily developed by Moore Engineering and Barr Engineering. These models underwent internal QA/QC reviews by Houston Engineering and HDR Engineering. The comments and responses from these reviews are included in Exhibit 5 of Appendix C. The QA/QC review of the LPP models was conducted after the January 31, 2011 report was submitted, with a goal of ensuring that the models were free of any significant issues for the February 28, 2011 submittal. With the extremely tight deadlines, the design team was unable to address every comment that was offered; however, the team is confident that any issues that could have potentially affected the results from the model were addressed. The remaining items are minor and do not need to be addressed for the February 28^{th} submittal.

C2.16 FUTURE IMPROVEMENTS AND MODIFICATIONS

With the aggressive timeline associated with Phase 4, certain features within the project design could not be fully analyzed. Additionally, the internal review revealed other aspects of the design that could use further refinement, but are deemed to be insignificant to the results. Throughout the design process, these issues were documented and prioritized for further evaluation as time allowed. A list of these items and a brief discussion of their relevance to the project are included below.

C2.16.1 Junction of Red River and LPP Diversion. From a spatial standpoint, the model appears to show that the junction of the LPP diversion channel with the Red River is downstream of the control structure on the Red River. The project design requires that the junction be located upstream of the control structure to allow the water to be diverted and staged, and the model is actually properly accounting for this. The connection reach of the diversion channel simply needs to be updated graphically in the spatial view within the model.

C2.16.2 Georeferencing of Cross Sections at Control Structures. From a spatial view, reaches for the Wild Rice and Red Rivers do not appear to correspond to the georeferenced cross sections associated with the control structures on those rivers. The cross sections were modified within the model to reflect the with-project conditions, which included the construction of new channels leading to and from the structures. The reaches in the model simply need to be adjusted graphically to correspond to the modified channel locations.

C2.16.3 Interpolated Cross Sections. The models currently contain numerous interpolated cross sections, most of which were added in an effort to stabilize the models. It is anticipated that some of these interpolated cross sections could be removed from the model without influencing the stability of the model. At minimum, the spacing of these sections, currently as short as one foot in some locations, could be expanded. Critical locations with interpolated cross sections could be replaced with actual georeferenced cross sections.

C2.16.4 Bridge Crossings in the Diversion Reaches. As noted in Section 2.14, the bridge crossings along the diversion reaches were not included in the models. In previous phases, the bridges were included but they were assumed to be elevated high enough that the low chords did not impede the flow within the diversion. That assumption was held with Phase 4, and it was also assumed that the channel cross section would not change through the bridge sections (past phases assumed a 5:1 (H:V) side slope through the bridge openings to narrow the length of the bridges). For future design considerations, it was noted that the bridge geometries should be included in the models, including the proposed piers, to obtain a more accurate representation of the actual design.

C2.16.5 Thompson to Drayton Reach. It was noted that additional detail could be included in the reach between Thompson and Drayton. This would include adding culverts and outlets to the storage areas within this reach to more accurately reflect the exchange of flows in the overbank and to allow these areas to drain after the levels in the Red River recede.

C2.16.6 Model Simulation Run Time. After reviewing the hydrographs for the existing and with-project conditions, it was noted that the hydrographs, particularly the ones on the downstream end of the model, did not have enough time to discharge the full volume on the receding limbs. While this volume is essentially trapped in the model at the end of the run, it should have no impact on the project design as it on the end of the receding limb and well after the peak. The simulation time should be extended to allow the system to fully drain. The simulation time will also need to be addressed if the model is extended farther downstream, as this will only become a bigger issue as the model is extended.

C2.16.7 Storage Area Volumes. During the internal QA/QC review process, multiple volume comparisons were completed to verify that the existing and with-project models were conveying the same amount of water. After refinements to storage areas and storage area connections in the model, including the addition of existing culvert crossings that were originally omitted from the models, the models for both conditions passed the same volume of water at a location downstream of the diversion outlet by the end of the simulation. There was, however, about 50,000 acre-feet of water that was left in storage at the end of the model run for both conditions. This volume is insignificant to the results as it accounts for only 1% of the total volume passing through the model at Drayton. A comparison of the models for both conditions revealed that the water was trapped in the same general areas for both cases and this issue was deemed to be minor as far the determination of project impacts was concerned. Some of the water was trapped in storage areas that either did not have any outlet at all or had outlets set above the bottom of the storage-elevation curve, both of which may actually exist in the real world. Further investigation into this trapped volume revealed that most of the water simply did not have enough time to drain from the storage areas back into the river reaches before the simulation ended. A simple review of the hydrographs for the storage areas on the downstream end of the models will reflect this. The inclusion of existing outlets that may have been omitted will reduce this volume, but extending the length of the simulation will account for most of the entrapped water.

C2.16.8 Side Ditch Inlets/Exterior Floodplain. As discussed in Section C2.10.7 further analysis is required for the sizing of the culverts and other inlet structures that drain the adjacent storage areas into the diversion. These structures need to be designed so that the floodplains associated with the independent peaks on the tributaries are maintained.

C2.16.9 Post Processing. Throughout the design analysis for Phase 4, issues were encountered with the post processing routine with HEC-RAS Version 4.1. Significant effort was put into debugging this issue, including consultation with software programmers at the USACE Hydraulic Engineering Center (HEC). In most cases, the models could be successfully post processed using the previous version (Version 4.0). At the present time, all of the models were able to completely process with a beta version of HEC-RAS Version 4.2 provided by HEC. This issue should be investigated further.

C2.16.10 Extreme Event Hydrology Analysis. As noted previously in this report, the Phase 4 design has not been fully analyzed for extreme event hydrologic scenarios, as was done for the previous phases. A brief analysis, documented in Appendix F, was done to determine design criteria for certain design features, but a full analysis should be completed.

C2.16.11 Potential Raise of I-29 South of Fargo. Preliminary modeling of a potential raise of Interstate 29 south of Fargo was completed to determine if connections would be necessary to allow water flow from one side of the highway to the other. The preliminary results indicate that there is only a minor differential in water surface elevations without any connections put in place. A more detailed analysis of this possible design component will be accomplished in future studies.

C3.0 RED RIVER DIVERSION – MODELING RESULTS

C3.1 RESULTS

The results of the unsteady state HEC-RAS hydraulic modeling for the LPP have been extracted from the models and processed for further analysis and simplified for a clear presentation within this report. The following sections include various representations and descriptions of the modeling results and the design for Phase 4.

C3.1.1 HEC-RAS Plan Files. Table C2 provides a listing of the HEC-RAS project and plan files for existing and with-project (LPP) conditions.

C3.1.2 LPP Diversion Profiles. Figure C7 and Figure C8 provide water surface profiles in the LPP diversion channel for the four synthetic design events and the four historic events, respectively. These profiles also show the bottom profile of the diversion in relation to critical subsurface soil layers.

C3.1.3 Red River Profiles, Tables and Graphs. Table C3 provides a summary of results from the HEC-RAS files for existing conditions for the synthetic design events.

Table C4 provides a summary of the results for the with-project conditions for the synthetic events. Table C5 is a summary of the results for existing conditions for the historic events and Table C6 summarizes the with-project results for those events. Figure C9 and Figure C10 depict the water surface profiles through the F-M Metro area for each of the modeled events.

C3.1.4 Stage-Frequency Curve at the Fargo USGS Gage. Figure C11 provides elevation and stage frequency curves for the range of synthetic flood events studied at the Fargo USGS Gage. The figures provide both existing and with-project conditions to allow for comparison.

C3.1.5 Discharge-Frequency Curve at the Fargo USGS Gage. Figure C12 shows the discharge-frequency curves for the Fargo USGS Gage for the existing and with-project conditions.

C3.2 IMPACTS

The proposed project, with either the FCP or LPP diversion alignment, impacts a much larger area than the Fargo-Moorhead metropolitan area. Depending on the location along the Red River, impacts of the project when compared to existing conditions may be adverse or beneficial in terms of discharges and stages during a flood event. While downstream impacts have been a major concern from the start of this study, the inclusion of staging on the upstream end of the project with the Phase 4 LPP design has resulted in significant impacts on these upstream areas. Although the FCP diversion was not redesigned during Phase 4 of the project, the Phase 3 design was modified and analyzed with the Phase 4 models in order to determine the impacts of that design. The new design for the LPP diversion developed in Phase 4 was also analyzed for impacts. In each case, impacts along the Red River were determined for a reach extending from Abercrombie, ND downstream to Drayton, ND, covering over 320 miles of the Red River of the North.

C3.2.1 Red River Impacts-FCP. The impacts of the Minnesota Diversion (FCP) project on the Red River from Abercrombie downstream to Drayton are included in Exhibit 1. Figures C-E1-1 through C-E1-8 reflect the project impacts at the landmarks shown the following table.

Landmark	Station
Drayton Gage	1062362
ND SH#17/ MN SH317	1223286
Co. Hwy 15	1315673
Oslo Gage	1416287
DS Grand Forks Levees	1533523
Grand Forks Gage	1558518
32nd Ave, Grand Forks	1580152
Thompson Gage	1667877
Co. Hwy 25/ Co. Rd 221	1726274
DS Sandhill River/ Climax	1763746
Nielsville	1829877
DS Marsh River	1864960
US Goose River/ Shelly	1891054
Halstad Gage	1981580
Hendrum	2038409
Perley	2129181
Georgetown	2193638
North River/ Clay Co. Hwy 93	2305647
19th Ave N Fargo/ 28th Ave N Moorhead	2360321
Fargo Gage (13th Ave S, 12th Ave S)	2388223
52nd Ave S Fargo/ 60th Ave S Moorhead	2438085
US ND Wild Rice River	2484618
Hickson Gage	2563878
Abercrombie	2764835

The impacts are shown in both tabular and graphical format for the four synthetic design events and the four historic flood events.

The remaining figures included in Exhibit 1 are hydrographs comparing the existing condition and with-project condition hydrographs at each landmark location. There are separate hydrographs for each of the four design events and the four historic events for each location. These figures are organized as shown below:

C-E1-1 -- C-E1-8 : Impact tables and charts
C-E1-9 -- C-E1-19 : 10-percent chance (10-year) hydrographs for FCP
C-E1-20 -- C-E1-30 : 2-percent chance (50-year) hydrographs for FCP
C-E1-31 -- C-E1-41 : 1-percent chance (100-year) hydrographs for FCP
C-E1-42 -- C-E1-52 : 0.2-percent chance (500-year) hydrographs for FCP
C-E1-53 -- C-E1-63 : 1997 historical flood hydrographs for FCP
C-E1-64 -- C-E1-74 : 2006 historical flood hydrographs for FCP
C-E1-75 -- C-E1-85 : 2009 historical flood hydrographs for FCP
C-E1-86 -- C-E1-96 : 2010 historical flood hydrographs for FCP

C3.2.2 Red River Impacts-LPP. The impacts of the North Dakota Diversion (LPP) project on the Red River from Abercrombie, ND downstream to Drayton, ND are included in Exhibit 2. Figures C-E2-1 through C-E2-8 reflect the project impacts at selected landmark locations along the entire reach. The landmarks selected for the LPP analysis correspond to the ones analyzed for the FCP, as discussed in Section 3.1.5. Likewise, the remaining figures included in Exhibit 2 are hydrographs comparing the existing condition and with-project condition hydrographs at each landmark location. These figures are organized as shown below:

C-E2-1 -- C-E2-8 : Impact tables and charts
C-E2-9 -- C-E2-19 : 10-percent chance (10-year) hydrographs for LPP
C-E2-20 -- C-E2-30 : 2-percent chance (50-year) hydrographs for LPP
C-E2-31 -- C-E2-41 : 1-percent chance (100-year) hydrographs for LPP
C-E2-42 -- C-E2-52 : 0.2-percent chance (500-year) hydrographs for LPP
C-E2-53 -- C-E2-63 : 1997 historical flood hydrographs for LPP
C-E2-64 -- C-E2-74 : 2006 historical flood hydrographs for LPP
C-E2-75 -- C-E2-85 : 2009 historical flood hydrographs for LPP
C-E2-86 -- C-E2-96 : 2010 historical flood hydrographs for LPP

C3.2.3 Mapping. The impacts of the FCP and LPP, in relation to increases and decreases in stages, were mapped to provide a more clear and concise means of determining the impacts. The maps included in Exhibit 3 depict the change in water surface elevations for with-project conditions versus existing conditions (without emergency protection) for each of the historic and synthetic design events for the LPP only. Exhibit 4 includes a collection of inundation maps for both the FCP and LPP. The downstream impacts are mapped for both the FCP and LPP and upstream impacts are mapped for the LPP. The maps in Exhibit 4 reflect the actual areas that will be impacted due to the stage increases or decreases shown on the maps on Exhibit 3.

C3.3 ANALYSIS

C3.3.1 Historic Events. As previously discussed, the work completed in Phase 4 includes the modeling of existing and with-project conditions for the four more recent larger flood events in Fargo-Moorhead (1997, 2006, 2009 and 2010). Although these model runs are not intended for project feasibility design or for flood damage reduction evaluation, they provide two very tangible benefits. First, these models offer the possibility to better communicate the project impacts to all stakeholders and the general public because they can relate to how the project would change the conditions that were experienced during the recent larger flood events. It is more reasonable to anticipate that this information could be conveyed in a clear way, as there is no need to explain concepts that are not familiar to a layperson, like the meaning of balanced hydrographs or return periods. However, the caveat to highlight is that the existing conditions models do not include the emergency protection measures that were in place during these historic events. The second benefit of having conducted these model runs is that they allow for estimation of how the magnitude and timing of tributary flows affect the magnitude and timing of flooding downstream; this is better captured with looking at the four historic events versus the synthetic event analysis.

In general, the comparison of existing conditions models and with-project models for these four historic flood events sheds light on the magnitude of upstream staging/storage that is required to eliminate impacts on flood levels downstream of the diversion outlet; for more details on the model results, see the impact tables included in the General Report and the impact tables included in Exhibits 1 and 2 of Appendix C. The review of the existing conditions model shows that the peak stage in the Red River of the North at Fargo was near 40 feet during the historic 1997 and 2009 flood events, whereas the peak stage at this location was near 37 feet during the historic 2006 and 2010 flood events. For additional reference, the first two larger flood events were close to a 2-percent chance event in Fargo, whereas the other two were close to a 5-percent chance event in Fargo. For the two larger historic flood events, if the water levels upstream of the diversion works are staged from modeled existing conditions 912-914 feet to modeled with-project 921-922 feet, then downstream impacts could be eliminated before reaching the downstream end of the model at Drayton. For the 2006 and 2010 events, staging would be from modeled existing conditions 910-911 feet to model with-project 919 feet in order to eliminate downstream impacts. Although the relative staging (difference in modeled with-project and existing conditions immediately upstream of the diversion works) is similar for the four events, it appears that the ultimate water surface elevation upstream of the diversion works is the one dictating the downstream impacts. In other words, the additional volume of approximately 75,000 acre-feet that can be staged and stored between 919 feet (approximately 125,000 acre-feet) and 922 feet (approximately 200,000 acre-feet) explains the elimination of downstream impacts for the two larger historic flood events. And this occurs even when the with-project stage at the Red River of the North in Fargo is very similar for the four historic flood events (29-31 feet). All of this suggests that in order to eliminate downstream impacts, upstream staging and storage to water surface elevations around 922 feet would be required, and more importantly, that the diversion works need to be operated not only based on peak flows but primarily based on total hydrograph volumes, in particular those during the rising limb of the hydrograph.

<u>C3.3.2 Design Events.</u> Work completed in Phase 4 also includes the modeling of existing and with-project conditions for four synthetic events (0.2-percent, 1-percent, 2-percent, and 10-percent chance design floods), which have been used for project feasibility design, flood damage reduction evaluation and impacts assessment on flood levels upstream and downstream of the proposed diversion. It is important to clarify here that the models referred to above and this discussion correspond to peak flows on the Red River of the North paired with coincidental events on the North Dakota tributaries. For project feasibility design, separate models have been created for cases of peak flows on the North Dakota tributaries paired with coincidental events on the Red River of the North in order to appropriately size the hydraulic structures in the North Dakota tributaries for extreme events in these rivers.

Before discussing the results of modeling existing and with-project conditions for the four synthetic events, a very important issue to bring attention to here pertains to the main design criteria used to develop the operational rules of the main line of flood protection at the Red River of the North and Wild Rice River because understanding of these criteria provides the context for qualifying the modeling results. These criteria are the following:

- To match the model Phase 3 with-project stage in the Red River of the North at the Fargo gage within ±0.15 feet, such that the difference in project benefits between the Phase 4 and Phase 3 feasibility designs is less than 5 percent (email communication from Lance Awsumb, USACE-PDT dated February 12, 2011);
- To eliminate impacts on floods levels downstream of the diversion channel outlet at a point that is located upstream of the Canadian border, such that the area to be impacted is well defined and NEPA requirements are met. The elimination of impacts is considered as a difference in water surface elevations between model with-project and existing conditions that is within ±0.04 feet. Because the tolerance used in HEC-RAS is 0.1 feet for water surface elevations, the precision of the model results is not greater than 0.1 feet. Therefore, the impacts on water surface elevations are rounded to the nearest 0.1 feet for flood management purposes, even though the model results are reported to the nearest 0.01 feet for transparency (email communication from Aaron Buesing, USACE-PDT dated January 25, 2011); and
- To limit the amount of staging upstream of the diversion works (in order to accomplish the two criteria above) without the need for an engineered storage area that encroaches too close into the urban centers within the protected area. It is an implicit goal to limit the extent of the area impacted, such that the number of structures affected with this Phase 4 feasibility design is less than that with the previous Phase 3 feasibility design.

The summary results of modeled existing conditions (which do not include emergency protection measures that were in place during the larger historic events) and modeled with-project conditions at gaged locations along the Red River of the North are presented in the General Report and Exhibits 1 and 2 of Appendix C. The review of the modeled existing conditions shows that the flows immediately upstream of the diversion works vary between approximately 10,300 and 28,600 cfs from the 10-percent to the 0.2-percent chance design flood, respectively. Accordingly, the modeled existing conditions flows and stage in the Red River of the North at the Fargo gage (which include the contribution of the Wild Rice River) vary between approximately 17,000 and 61,700 cfs and between approximately 34.6 and 43.1 feet, respectively, from the 10-percent to the 0.2-percent chance design flood. For the two larger synthetic events (i.e., the 0.2-percent and 1-percent chance design floods), if the water levels upstream of the diversion works are staged from modeled existing conditions 915-916 feet to modeled with-project 922-923 feet, then downstream impacts could be eliminated before reaching the downstream end of the model at Drayton and the modeled with-project stage in the Red River of the North at the Fargo gage is within ±0.15 feet of the Phase 3 values. This range of staged water surface elevation upstream of the diversion works is similar to that obtained for the two larger historic flood events in the Red River of the North at Fargo (i.e., 2009 and 1997), and it reinforces the suggestion that in order to eliminate downstream impacts for extreme floods, upstream staging and storage to water surface elevations near 922 feet would be required.

When looking at the magnitude of the relative staging upstream required to eliminate downstream impacts for the smallest synthetic event analyzed (i.e., the 10-percent chance design flood), from water surface elevation 908.1 feet for modeled existing conditions to water surface elevation 916.3 feet for modeled with-project conditions, it becomes clear that the diversion works need to be operated not only based on peak flows but primarily based on total hydrograph volumes, in particular during the rising limb of the hydrograph. That is, the overall performance of the diversion works (to meet the three main design criteria listed above) depends on the trade-off between storage (upstream staging or Storage Area 1) and release (either through the diversion channel or the control structure on the Red River of the North) of the incoming flood flows and volumes during the rising limb of the hydrograph. This in turn may imply that, as found during several trial runs of the HEC-RAS unsteady flow model for with-project conditions, allowing more water to pass into the protected area through the control structure on the Red River of the North does not necessarily help to eliminate impacts downstream if the timing of this release is similar to the timing of the peak flows and flood volumes being conveyed through the diversion channel. Indeed, it was found that the best operational scheme of the gates in the control structure on the Red River of the North (the best to eliminate downstream impacts without increasing the upstream staging) was the one that decoupled the peak flows and flood volumes conveyed through the diversion channel from those passing into the protected side. Thus, for all synthetic events, the operational scheme of these gates proposed at this feasibility level is to progressively close them during the rising limb until approaching (but before) the peak of the incoming hydrograph, keep them at their lowest position until the peak flows and flood volumes in the diversion channel have exited the diversion, and then progressively open the gates to reach the Phase 3 stage in the Red River of the North at the Fargo gage.

Two final issues deserve some discussion here. The first one derives directly from the previous paragraph. With the operational scheme of the gates in the control structure on the Red River of the North proposed at this feasibility level, there is room for increased flood damage reduction, especially for the 0.2-percent chance event. Recall from summary tables that the modeled with-project stage in the Red River of the North at the Fargo gage is estimated at approximately 40 feet. This stage is very similar to the one during the flood of record in 2009, when the cities of Fargo, ND and Moorhead, MN (with support from the USACE) had to implement a very extensive and significant emergency protection plan. We anticipate that a lower with-project stage for the 0.2-percent chance event would be welcome by the local sponsors. The second issue relates to the start and end of the gates operation (in relation to the peak of the flood hydrograph) and their implications on the duration of high stages and fish passage conditions in the Red River of the North, including the functioning of the fishways. From our work to date, it is reasonable to expect that in the next stage of design the operational scheme of the gates in the control structure on the Red River of the North can be optimized to reduce the duration of high stages and to further minimize the restriction on fish passage.

C3.3.3 Timing of Flood Peaks. The LPP diversion causes a change in the hydrograph timing along the Red River when compared to existing conditions. With the LPP diversion, the peak of the flood hydrograph along the Red River downstream of the diversion is shifted ahead in time between 12 and 24 hours. This shift in timing coincides with tributary hydrographs downstream of the diversion, which advances in time the peak in both discharge and stage. As a result of this occurrence, the design of the diversion and the elevation of the staging area upstream of the project area was designed such to minimize the increased water surface elevations downstream of the project area. These hydrographs are shown in detail in Exhibit 2 of Appendix C.

C4.0 REFERENCES

A- Houston Engineering, Inc., Technical Support Data Notebook for Stanley and Pleasant Townships, Cass County, ND and Holy Cross and Kurtz Townships, Clay County, MN Flood Insurance Study, January 5, 2006.

B - Houston Engineering, Inc., Technical Support Data Notebook for City of Fargo, North Dakota Flood Insurance Study, October 8, 2007.

C - Moore Engineering, etal., Red River Diversion, Fargo-Moorhead Metro Flood Risk Management Project, Feasibility Study, Phase 2, Report for the US Army Corps of Engineers, and the cities of Fargo, ND & Moorhead, MN, August 31, 2009.

D- Moore Engineering, etal., Red River Diversion, Fargo-Moorhead Metro Flood Risk Management Project, Feasibility Study, Phase 2, Report for the US Army Corps of Engineers, and the cities of Fargo, ND & Moorhead, MN, Appendix H-Red River Diversion Hydraulic Structure Velocities, October 15, 2009.

E - Moore Engineering, etal., Red River Diversion, Fargo-Moorhead Metro Flood Risk Management Project, Feasibility Study, Phase 2, Part 2, Report for the US Army Corps of Engineers, and the cities of Fargo, ND & Moorhead, MN, December 31, 2009, Revised January 6, 2010.

F- Moore Engineering, Fargo-Moorhead Metro Flood Risk Management Project, Feasibility Study, Report for the US Army Corps of Engineers, and the cities of Fargo, ND & Moorhead, MN, Northwest Diversion Channel, January 28, 2010, Revised March 4, 2010.

G - Moore Engineering, etal., Red River Diversion, Fargo-Moorhead Metro Flood Risk Management Project, Feasibility Study, Phase 3, Report for the US Army Corps of Engineers, and the cities of Fargo, ND & Moorhead, MN, May 17, 2010.

H - Moore Engineering, etal., Red River Diversion, Fargo-Moorhead Metro Flood Risk Management Project, Feasibility Study, Phase 3 (Phase 3.1 Hydrology), Report for the US Army Corps of Engineers, and the cities of Fargo, ND & Moorhead, MN, July 30, 2010, Updated August 11, 2010.

I - Moore Engineering, etal., Red River Diversion, Fargo-Moorhead Metro Flood Risk Management Project, Feasibility Study, Phase 4, Report for the US Army Corps of Engineers, and the cities of Fargo, ND & Moorhead, MN, January 31, 2011

J - Moore Engineering, etal., Red River Diversion, Fargo-Moorhead Metro Flood Risk Management Project, Feasibility Study, Phase 4, Alternative Scenarios Analysis, Report for the cities of Fargo, ND & Moorhead, MN, April 8, 2011

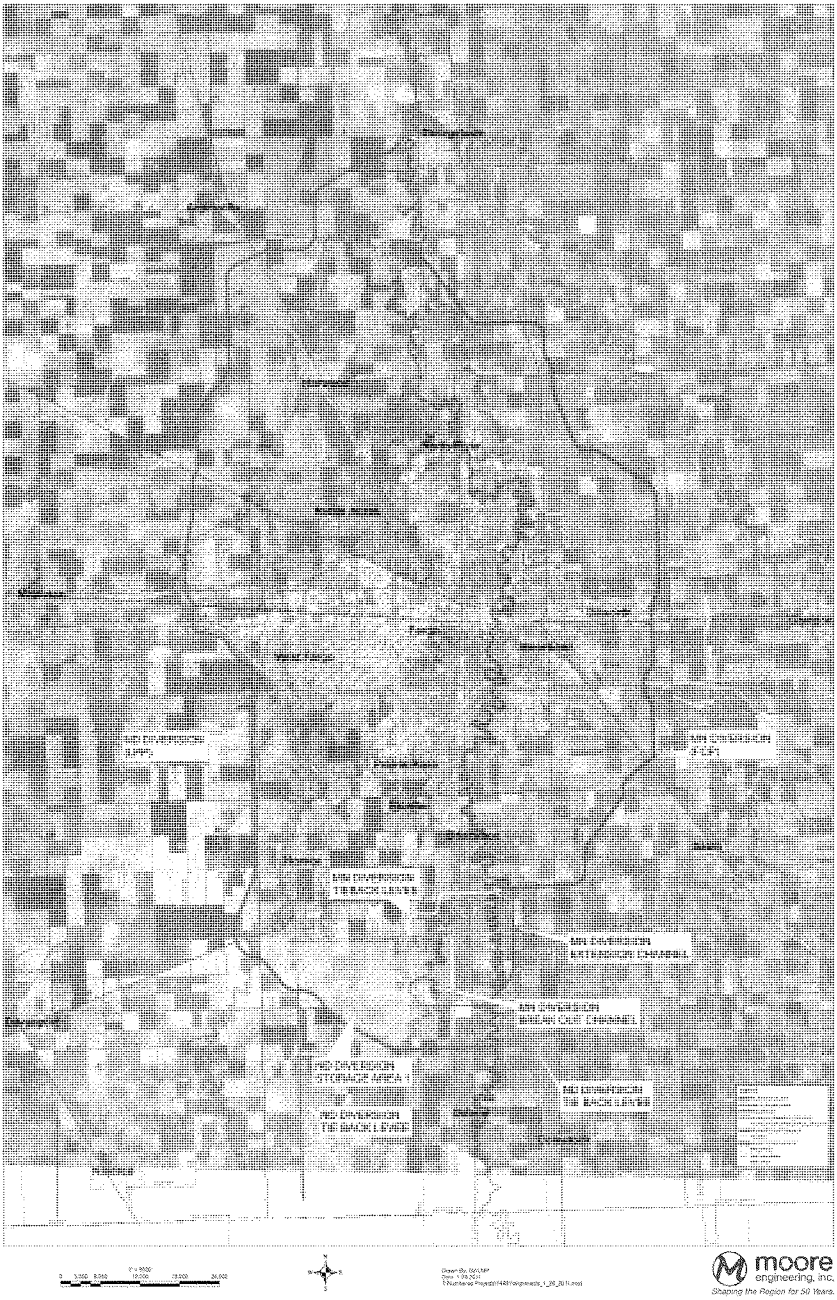

Figure C1-Red River Diversion Channel Alignments (FCP and LPP)

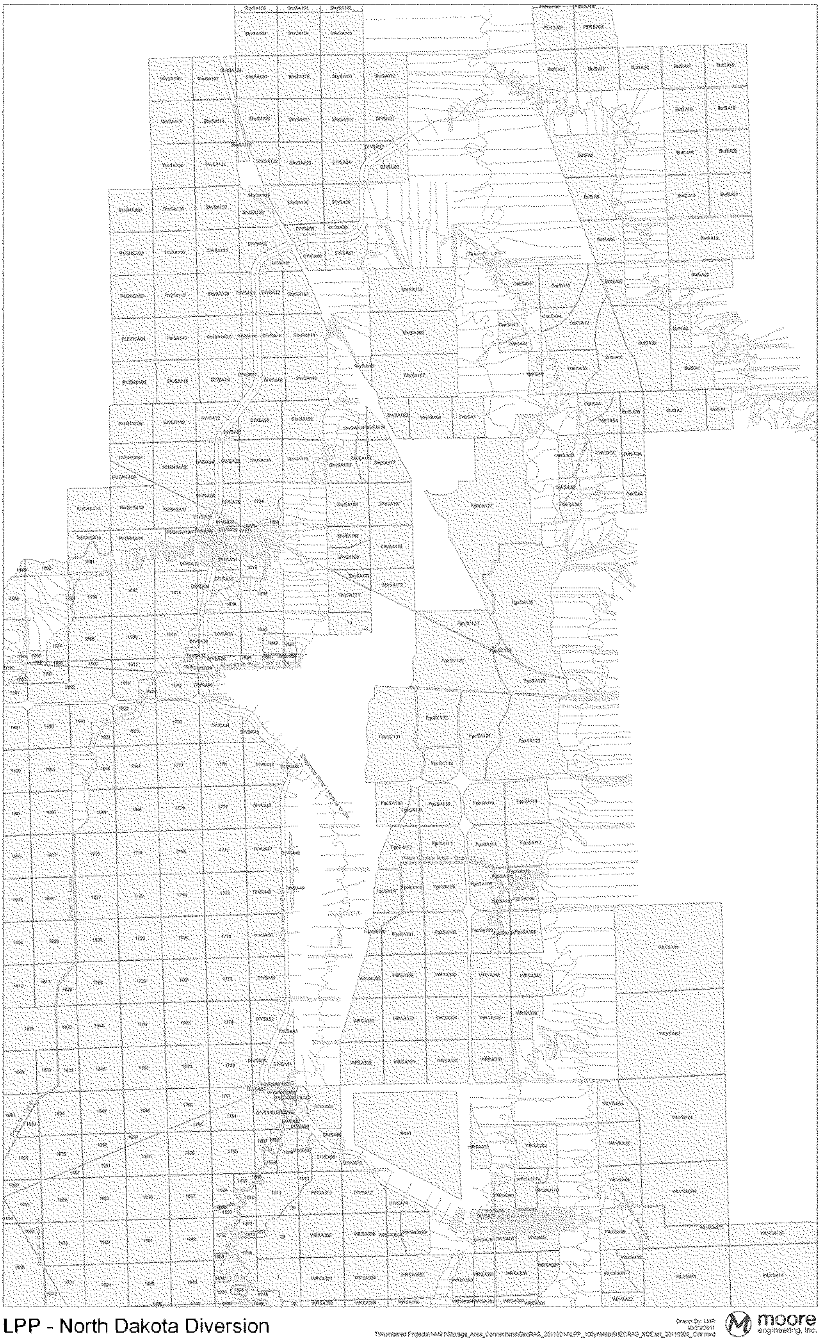

Figure C2-HEC-RAS Georeferenced Cross-Sections for the LPP

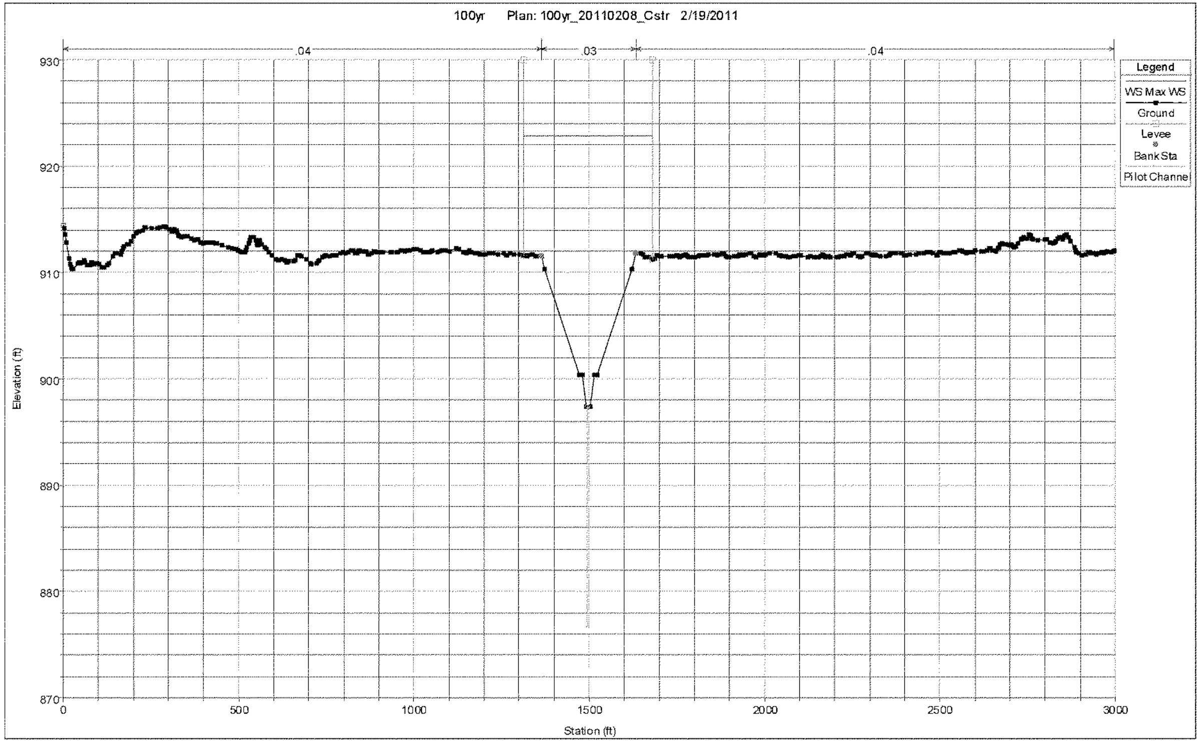

Figure C3- Typical HEC-RAS Model Cross Section -LPP Connection Channel

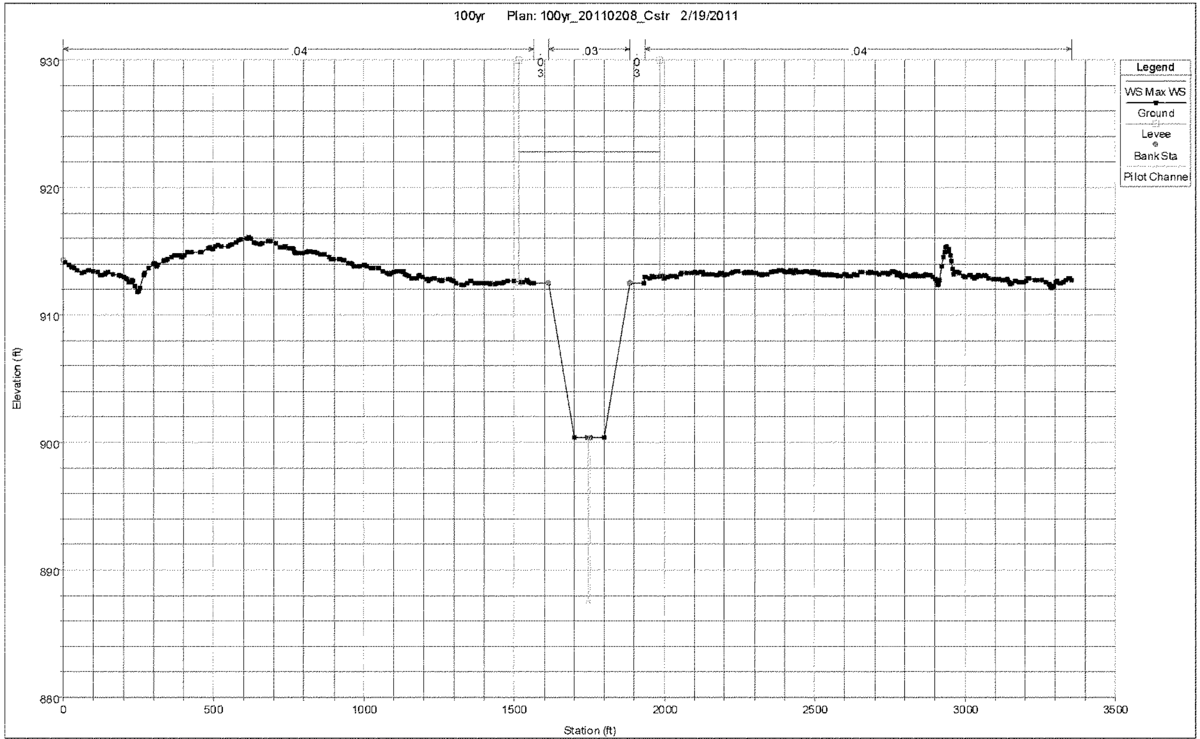

Figure C4- Typical HEC-RAS Model Cross Section- LPP Diversion Upstream of the Diversion Inlet Weir

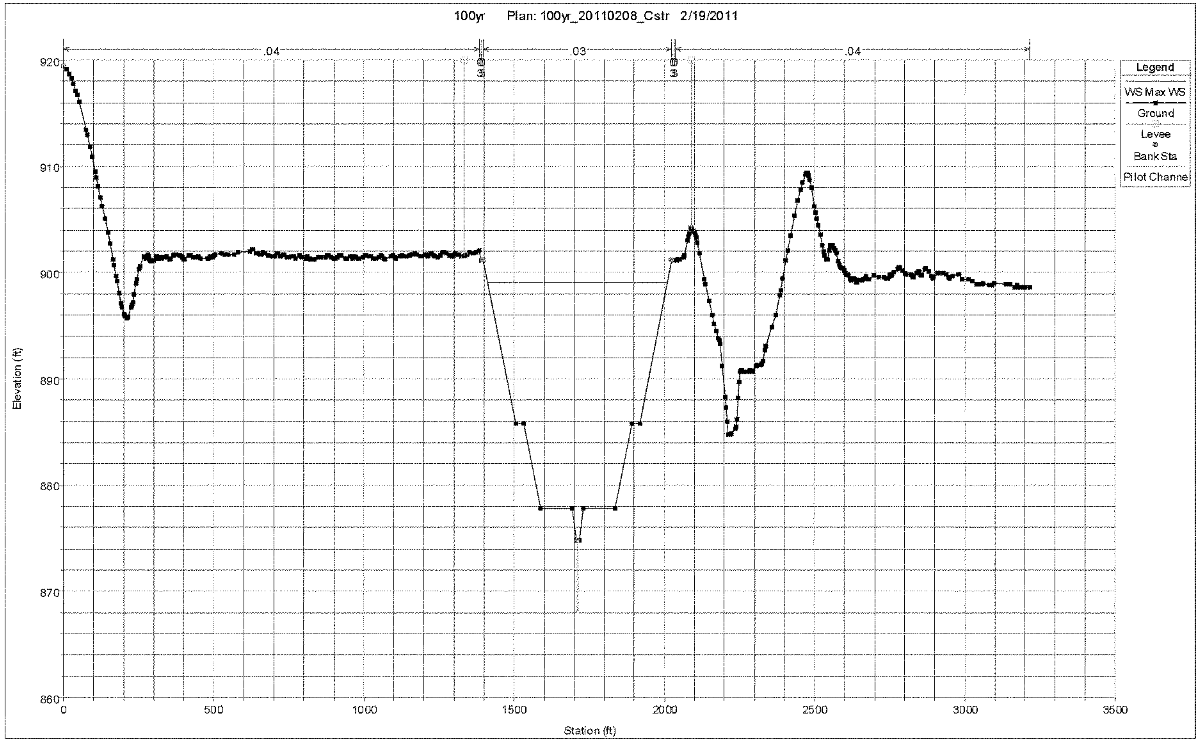

Figure C5- Typical HEC-RAS Model Cross Section- LPP Diversion Downstream of the Diversion Inlet Weir

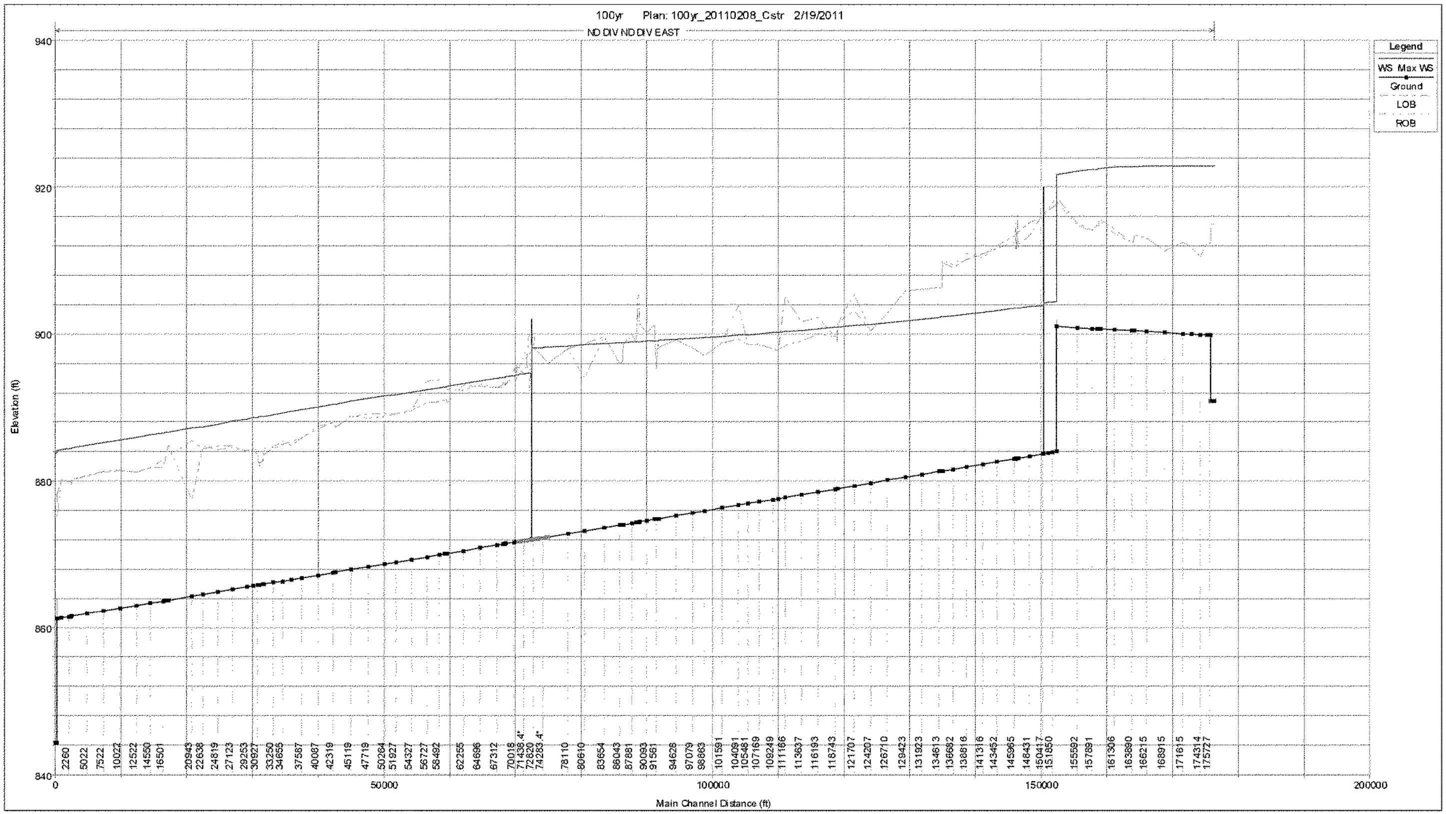

Figure C6- HEC-RAS Model Profile- LPP Diversion Channel

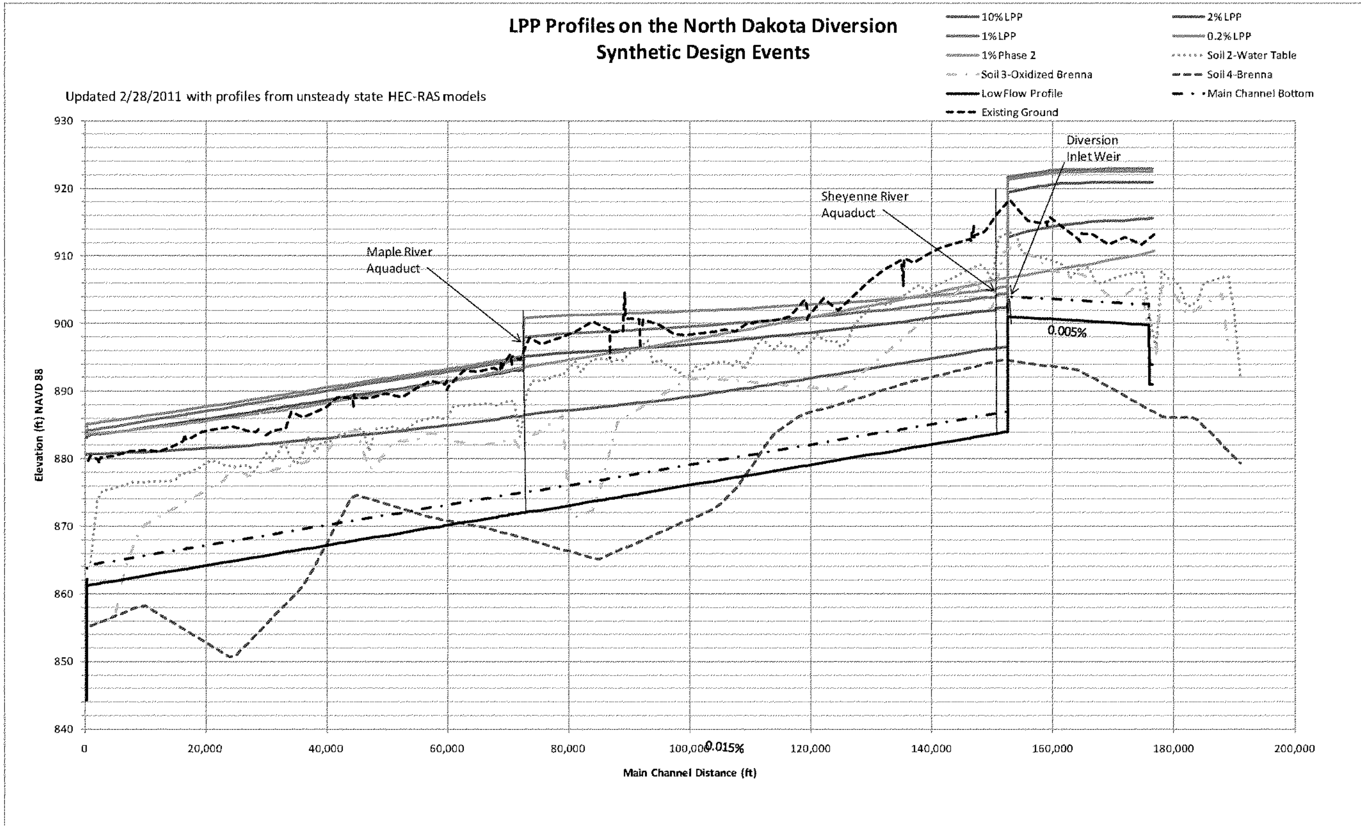

Figure C7-LPP Profiles on the North Dakota Diversion- Synthetic Design Events

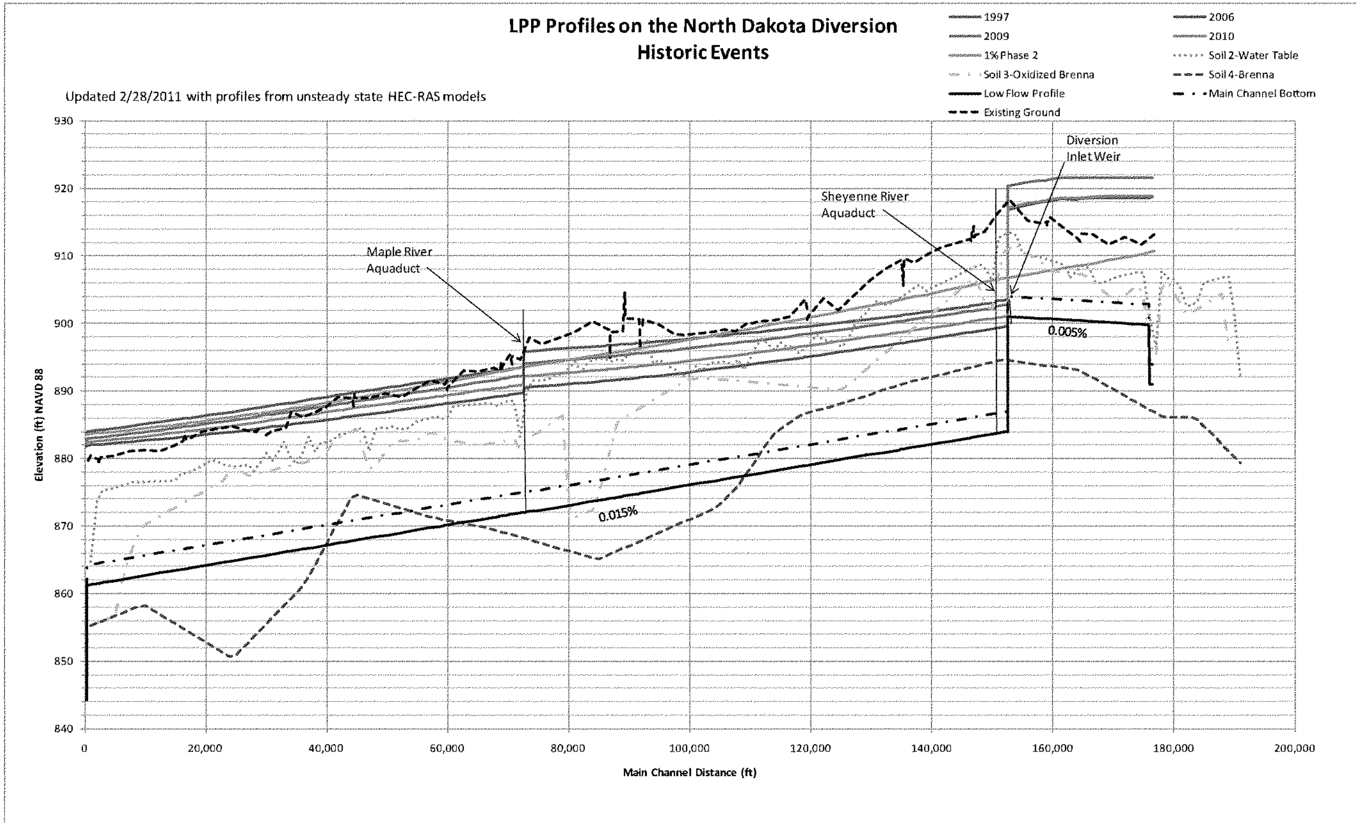

Figure C8- LPP Profiles on North Dakota Diversion-Historic Events

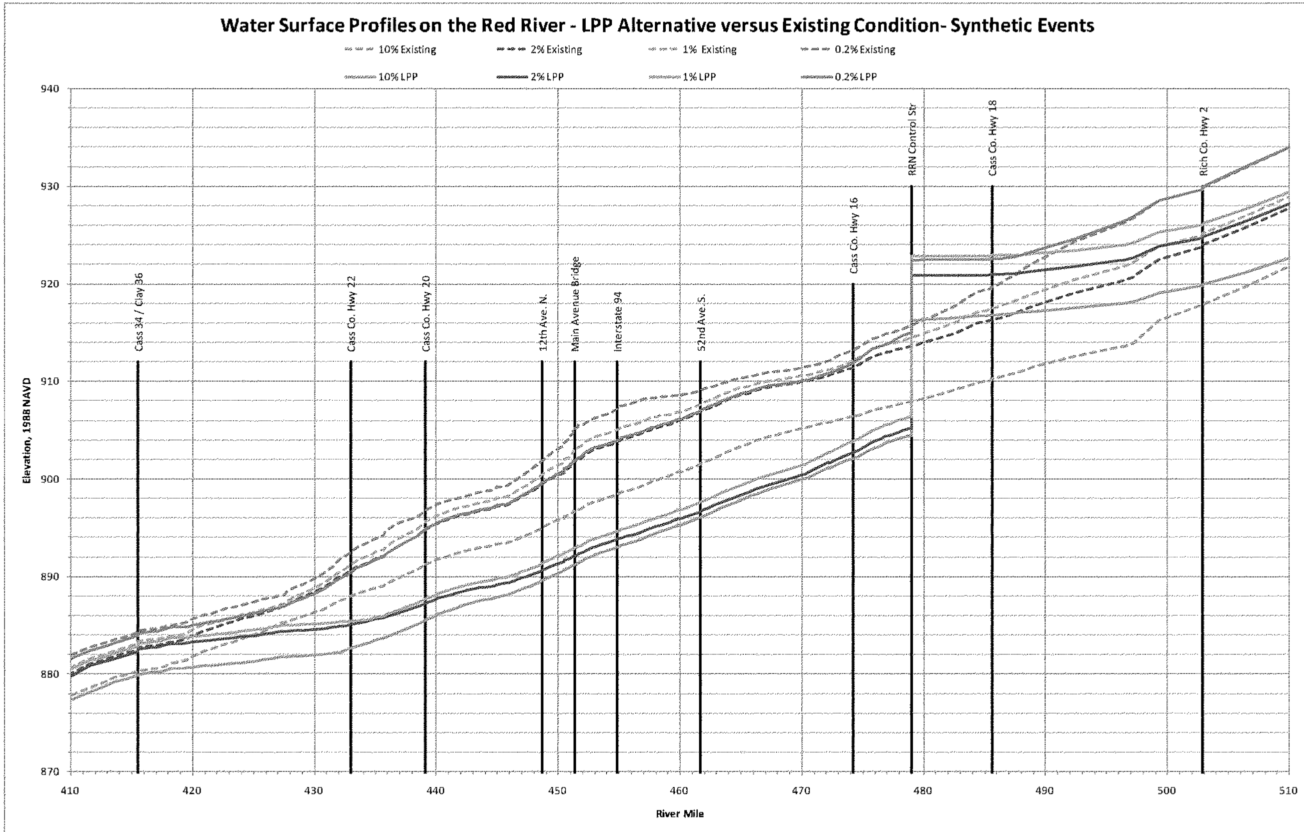

Figure C9-Water Surface Profiles on the Red River- LPP vs. Existing Conditions – Synthetic Design Events

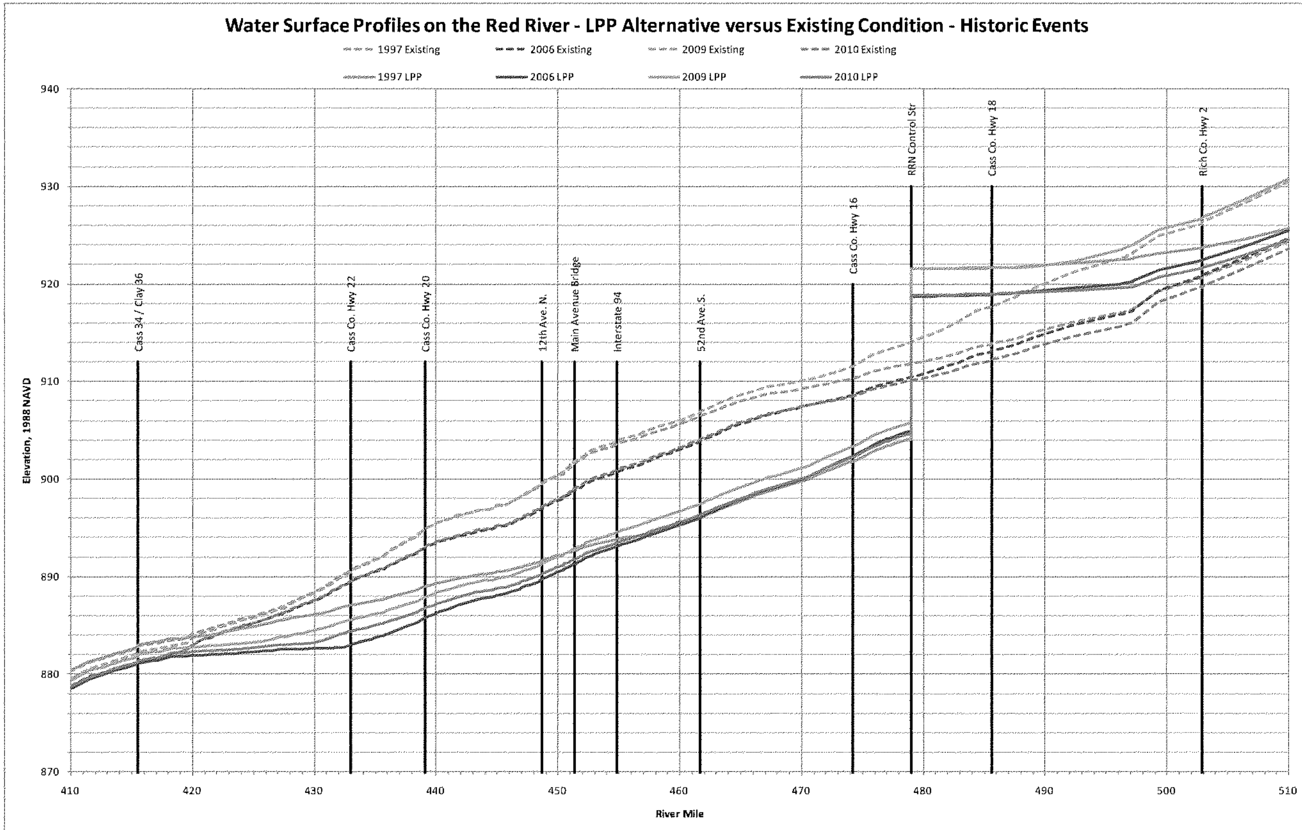

Figure C10-Water Surface Profiles on the Red River- LPP vs. Existing Conditions – Historic Events

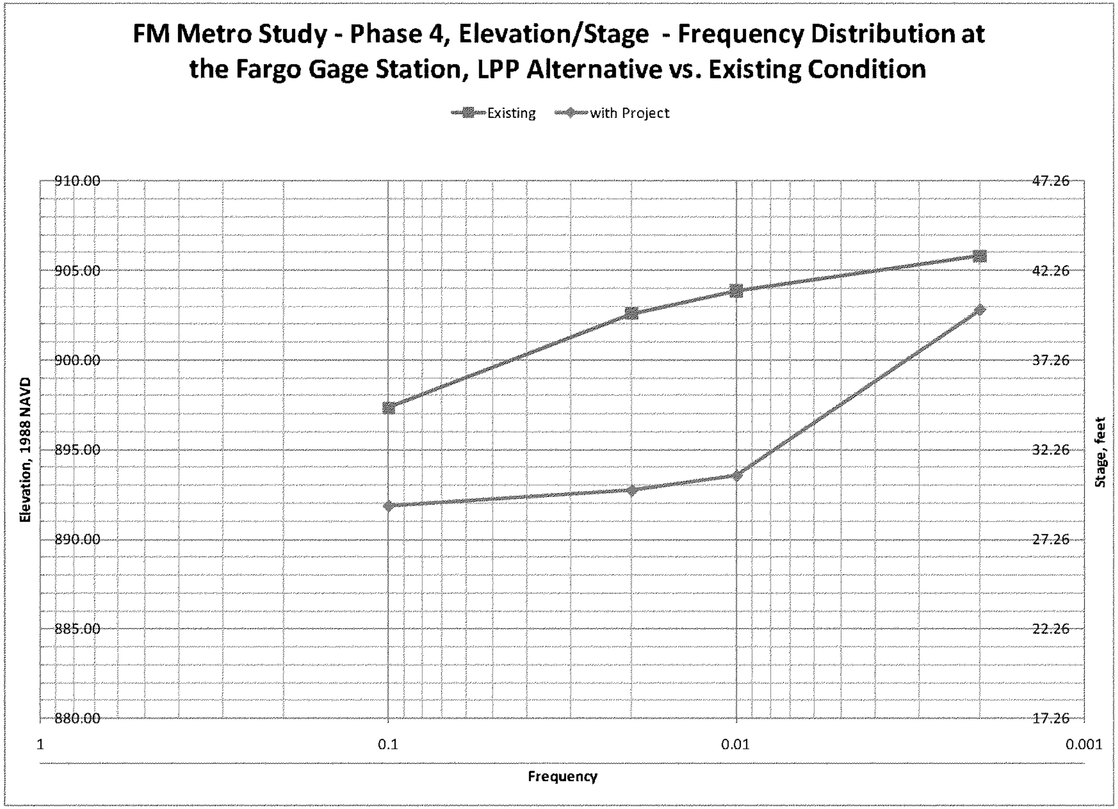

Figure C11-Elevation/Stage - Frequency Distribution at the Fargo Gage Station, LPP vs. Existing

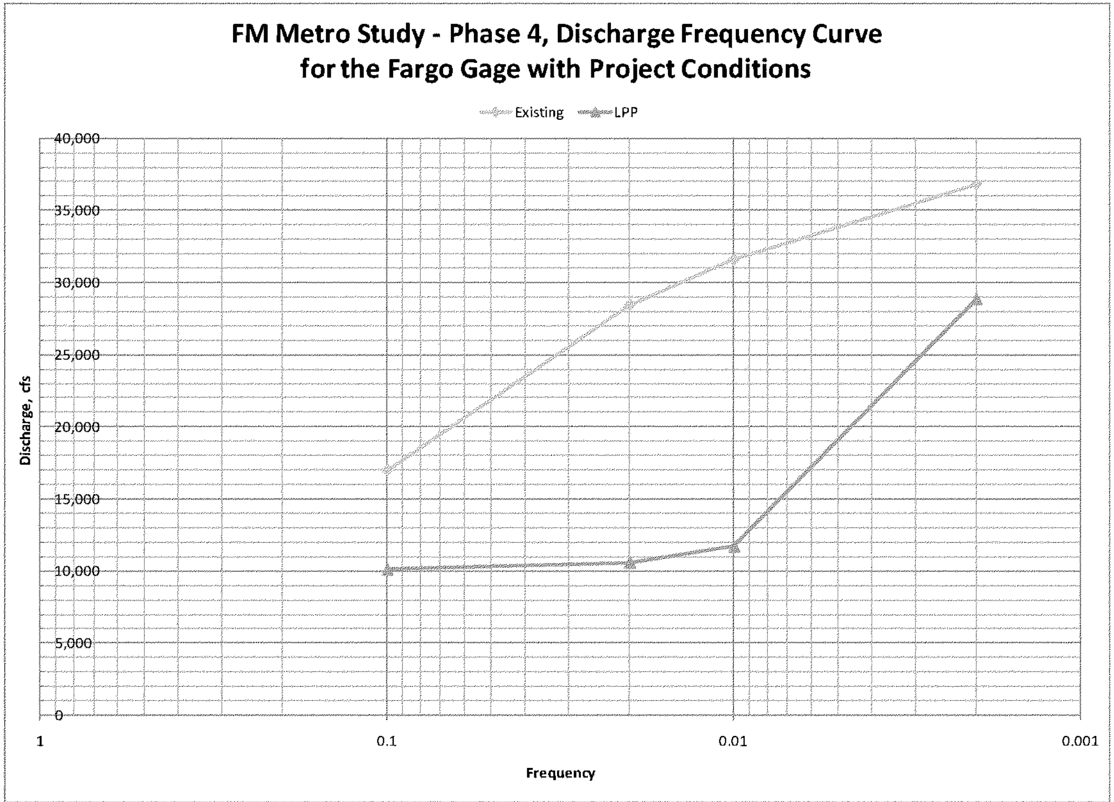

Figure C12-Discharge Frequency Curve for the Fargo Gage with LPP

FOR CONTINUATION OF HOUSE DOCUMENT 112-130

FEASIBILITY REPORT AND ENVIRONMENTAL IMPACT STATEMENT: FARGO-MOORHEAD METROPOLITAN AREA FLOOD RISK MANAGEMENT, JULY 2011

SEE PART 2